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A PHYSICAL ESSAY ON THE SENSES.

Translated from the FRENCH of

M. *LE CAT.*

Illustrated with COPPER-PLATES.

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A PHYSICAL ESSAY ON THE SENSES.

Of the TOUCH.

THE TOUCH participates of leſs Delicacy than the other Senſes; but at the ſame Time ſurpaſſes them in point of Certainty. It abſolutely cuts off all Incredulity; beſides which good Property, it enjoys that of being the moſt general Senſation. Seeing and Hearing reſult from the Organization of a very minute Portion of our Structure; but it is requiſite that every Part of the animal Œconomy ſhould be endued with the Faculty of Feeling, to diſtinguiſh us from mere Machines, that may be taken to pieces at pleaſure, without the Conſciouſneſs of any Violence offered to their Mechaniſm. This is what Nature has furniſhed; and wherever we find Nerves and Life, there alſo ſubſiſts this Sort of Senſation; which does not ſeem to ſtand

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in need of any particular Organization, or to depend on the Structure of the nervous Papillæ, the simple solid Texture of the Nerve being alone sufficient to produce it. The Lips of a green Wound, the Periosteum, or a Tendon, laid bare, have a very quick Sensation, tho' destitute of the nervous Papillæ observable on the Skin. Nature, whom one would conclude necessarily obliged to be at a great Expence in producing this Sense of the Touch, has nevertheless established it at a small one. So that the nervous Papillæ are not absolutely necessary to Feeling, but to the Perfection of it, and the Variety of the respective Sensations. The Sense of Feeling therefore is as the Basis of all other Sensations. 'Tis the Genus, of which they are the most perfect Species. All the nervous Solids, animated by a Fluid, are endued with this general Sensation. But the Papillæ of the Skin, those of the Fingers for example, enjoy it to a Degree of Perfection; which adds to the first Sensation a Sort of Discernment of the Figure of the Body touched. The Papillæ of the Tongue surpass those of the Skin; and, in short, those of the Nose the Papillæ of the Tongue: and so of the rest in Proportion to the Delicacy of the Sensation. What I am advancing, in regard of the Papillæ, does not at all exclude the rest of the nervous Texture from the Share it has in causing Sensation. The Papillæ are more concerned than this Texture, in particular

The Senses in general are but Modes of Feeling in more or less Perfection.

cular Organs, as on the Skin, and the Tongue. In others they have a leſs Portion aſſigned them; namely, in reſpect of the Noſe, or the Pituitary Membrane, which conſtitutes the Organ of Smelling. In ſhort, in other Places the Papillæ ſeem to have ſtill a leſs Share; and the ſolid nervous Texture almoſt ſingly compoſes the Organ as in the Sight. Theſe Differences proceed from each Organ's being proportioned to the Object whoſe Impreſſion it receives. It would be very conducive to the Perfection of the Touch, were the Nerves to form ſmall ſenſible Eminences: becauſe theſe Sort of ſharp pointed Subſtances are more eaſily irritated by the Surface of Bodies, than an uniform Texture could poſſibly be. The Taſte would require nervous Papillæ, that ſhould be of a ſpungy Nature, and at the ſame time ſufficiently impregnated with Moiſture, to dilute and diſſolve the Principles of Taſte, and to admit them eaſily into their Texture, in order to their making a more lively Impreſſion. The pituitary Membrane that lines the Organ of the Smell is furniſhed with ſoft, downy, Windings, and little Cells, to confine the odoriferous Vapours; but, its Object being ſubtile, it would have no Occaſion either for Papillæ, or ſenſible Points. The Choroides, the immediate Organ of Sight, has likewiſe its ſoft black Down, to abſorb the Images that make its Object: but the Bottom of theſe velvet Subſtances, formed to receive the

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The Touch. Images, ought to be a nervous Membrane, very ſmooth and very ſenſible.

All Matter of ſufficient Conſiſtence or Solidity to affect the Surface of our Skin, becomes the Object of the Touch. This Senſe aſcertains the Bulk, and Figure of Bodies, their Diſtance, Inaction, Motion, Solidity, Softneſs, Fluidity, Heat, Coldneſs, Dryneſs, Moiſture, *&c.* Theſe are its proper Objects.

Objects of the Touch.

Heat. The Senſation of Warmth, or Heat, is a Sort of light Emotion, or Irritation of our nervous Parts, and an Expanſion of our Solids and Fluids, produced by the ſlight Action of a moderate Quantity of the ſubtile Matter that compoſes Fire, or the Origin of Heat, whether natural or artificial.

When this Matter either exceeds in Quantity, or is more than ordinarily agitated, then, inſtead of irritating or expanding our Solids and Fluids, it tears them, and diſſolves them ; and this Violence of Action cauſes an Inflammation.

Cold. The Senſation of Cold, on the contrary, is a Sort of Obſtruction in the nervous Papillæ, and generally in all the Solids, and a Condenſation, or Defect of Motion, in our Fluids ; ariſing either from the Contact of ſome cold Subſtance, that is to ſay, of a Subſtance that is not to any degree impregnated with ſubtile agitated Matter, like the Air, or Water, in Winter ; or by any other accidental Cauſe, whereby the Motion of our Fluids and natural Elemental Heat is ſuppreſſed,

preſſed, like the Periodical Convulſion of the Solids that produces the Shivering in an Ague. It is probable, that our Fluids being either totally condenſed, or impeded in their Motion, by one or other of theſe Cauſes, the nervous Papillæ, and the Solids in general, which are ſolely expanded by the Impulſe of theſe Fluids, are immediately blocked up; and it is this Conſtipation, that is the Source of all the Effects of Cold in the Human Body.

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Structure of the Skin.

The Skin, the Organ of the Touch, is a Compoſition of Fibres, Nerves, and Veſſels, which are interwoven one with the other in ſuch an extraordinary manner, that the Texture in ſome meaſure reſembles Network.

This fibrous Texture is viſible in thick Shammy, and in the Soles of Shoes made of a thick and ſoft Leather, where, indeed, the Fibres appear very diſtinctly.

The Skin adheres to all the Parts it incloſes, by means of Blood-Veſſels, Lymphatics, Nerves, and ſometimes of fleſhy Fibres, as in the Face; but commonly by ſeveral very thin complicated Foliages, which form themſelves into little Cells, where the Extremities of the Arteries ſecern an Oil, termed Fat. The Anatomiſts call theſe *Strata* of Foliages the *Cellular Membrane*, or *Membrana Adipoſa*: Its Structure pretty much reſembles that of a Puff-Paſte Cake. It is here the Butchers introduce the Air, when they blow

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their Meat, to render it more agreeable to the Eye.

The Skin is formed of all the Parts themselves that fasten it to the Body which it infolds. These Foliages, Vessels, and Capillary Nerves are determined one over the other by the Compression of the Waters that surround the Fœtus in the Womb, and, after its Birth, by the Pressure of the Atmosphere. These Fibres, being thus interwoven and pressed together, form the Substance we have been describing. Several of these Vessels, originally hollow, acquire in a short Space a firm Solidity, and become as it were tendinous; and are, with the Nerves, the principal Substance of this thick Texture.

The nervous Capillaries, after having concurred, by their twining and running across one another, to the Formation of the Skin, terminate in its external Surface; where they shed their first Coat, to wit, That supplied by the *Dura Mater*. This first Coat, commonly stiled the Sheath of the Nerve, is divided into several Shreds, that stick entangled together on the Surface of the Skin, and by that means constitute a Sort of Network, called the *Reticulary Body*.

The perfect Organ of the Touch.

The Mechanism of this nervous Network is very well accommodated for receiving the Impression of Objects: but the Extremity of the Nerve, stripped of this first Coat, expands and raises itself between the Interstices of this Net-

work,

work, and forms the nervous Papillæ. Theſe are elevated above the Network, are far more ſuſceptible of Irritation, and, conſequently, intirely formed for the Production of the moſt perfect Senſation. A ſpirituous Lymph moiſtens theſe Papillæ, renders them ſupple and elaſtic, and of courſe furniſhes an Organ in all reſpects compleat and accompliſhed.

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Theſe Papillæ are ranged in Lines, and in a certain Order. And it is this Order that produces the little Ridges obſervable on the Cuticle, or Scarf-Skin, and ſo viſible at the Ends of our Fingers, where they are ſpiral.

The nervous Papillæ are perpendicular to the Surface of the Body. At the Ends of the Fingers they are lengthened in Proportion to the Extent of that Part, and are ſo cloſely connected together, as to form thoſe ſolid Bodies, the *Nails*.

Their very ſtrait Union is the Reaſon why there is no Paſſage for the animal Fluid thro' this Compoſition, whence the Nail becomes inſenſible. But, to make amends, at the Root of the Nail, where the nervous Papillæ are very ſolid, very elaſtic, and remain open to the Flux of Spirits, the Senſation is extreme.

The ſanguinary, lymphatic, and oily Capillaries, that penetrate the Texture of the Skin, are diſtributed almoſt like the Nerves. Being interwoven one with another in the Skin, they form the vaſculary Network. Their Expanſion

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on the Surface of the Skin constitutes the Excretory Vessels, and the Cuticle that invests the Papillæ, and is very necessary to them, by softening the Impression of Objects; and rendering by that means the Perception more distinct. In short, to this Structure, so adapted to the forming the Organ of the Touch, we must add the Glands situated under the Skin; which serve to supply, at the End of the Lymphatics, the Spirits necessary for the Lymph that moistens the nervous Papillæ, and to bestow on the Animal Fluid a Preparation requisite to the Perfection of this Sensation.

Advantage of the Touch.

The Sense of Feeling is absolutely so compleat, and of such universal Benefit, that it has sometimes performed, if I may so express myself, the Function of the Eyes, and recompensed, in some measure, the Blind for the Loss of their Sight.

Historical Relations on this Subject.

An Organist in *Holland*, tho' deprived of his Eyes, could notwithstanding play perfectly well. He had acquired likewise a Habit of distinguishing by the Touch the different kinds of Money, and even Colours. Cards could not escape the Delicacy of his Fingers, by which means he became a formidable Gamester: For, in dealing the Cards, he knew the Hands of those he played with, as well as his own.

The Sculptor *Ganibasius* of *Volterre* still surpassed the Organist I am speaking of. It was sufficient for this blind Artist to have touched an Object,

Object, in order to make a Buſt in Clay, that ſhould bear an exact Reſemblance. The Touch.

Theſe are the Perfections of the Touch, exceeding all Imagination, and indeed Belief, were they not very well atteſted. In the mean while, I am apt to think that this latter Inſtance does not depend ſo much on a perfect Senſation, as on an extreme lively Imagination. There is no one, but may diſtinguiſh the Inequalities of a Face with his Fingers; but, perhaps, it was the peculiar Privilege of the Sculptor *Ganibaſius*'s Imagination, to be capable of conceiving an exact Likeneſs, by the Inequalities perceived by the Touch, and of executing it afterwards in Clay.

Tickling.

One Perfection of the Touch, common enough indeed, but for this very Reaſon worthy of our Obſervation, is *Tickling*, a Sort of Hermaphrodite Senſation; productive of Pleaſure, of which it is an Extreme; and of Pain, of which it is as it were the firſt Degree. Tickling makes us laugh, and at the ſame time is inſupportable. And, if you carry it too far, it becomes a real Evil, and even a mortal one, if any Credit is to be given to Writers on that Subject. This Senſation, therefore, muſt conſiſt in a ſlight Stimulating of the Organ of the Touch, like the Irritation that produces all voluptuous Senſations; but what is at the ſame time ſtill of more Energy, and even quick enough to throw the Soul and Nerves into Emo-

Tickling. tions and Agitations, more violent, than what uſually reſult from Pleaſure: and, on that account, this Irritation approaches very near to the Attacks that excite Pain.

The lively Irritation that cauſes Tickling, proceeds, firſt, from a Sort of Impreſſion made by the Object, as when the Lips are lightly ſtroked with a Feather: ſecondly, from the Diſpoſition of the Organ extremely ſenſible, namely, the nervous Papillæ of the Skin, being very numerous, very ſuſceptible of Irritation, and furniſhed with abundance of Spirits. For this Reaſon, Bodies of a moſt ſenſible and moſt lively Temperament, and the Parts that are beſt ſupplied with Nerves, are alone ſubjected to being tickled. The Organ may moreover be endued with a Senſibility, as it is neceſſary it ſhould be in order to produce a Tickling, by a Diſpoſition inclining a little to an Inflammation. To this Cauſe thoſe Itchings muſt be aſcribed, where a light Scratching is the Source of ſo great a Pleaſure. But this Pleaſure, like Tickling, borders very much on Pain.

Imagination productive of the Senſe of Tickling.

Beſides theſe Diſpoſitions of the Object, and of the Organ, Imagination has likewiſe a great Share in this Senſation of Tickling, as well as in all other Senſations.

If any one touches us in the moſt inſenſible Places with a profeſſed Intention to tickle us, we cannot bear it. On the contrary, if the Hand be applied to our Skin indifferently, without that ſeeming

ſeeming Intention, we are not ſenſible of any extraordinary Impreſſion; and, in the moſt ticklish Parts, we can touch ourſelves with all the Tranquillity imaginable. Surprize therefore, or Miſtruſt, is a neceſſary Requiſite to diſpoſe the Organs and the Object for Tickling. This Affection of the Soul determines her to diſpatch a greater Quantity of Spirits to theſe Organs, and to all the Muſcles that have any Connexion with them. She there puts them on Action, and by that means renders both the Organ more lively and ſenſible, and the Muſcles ſuſceptible of Contraction on the leaſt Impreſſion. It is a kind of Terror in the Organ of the Touch; which may be compared to that a Hare is under, when ſhe hears the Cry of the Dogs.

Tickling.

A Prieſt who could deprive himſelf of all his Senſes.

This odd Phœnomenon, in regard of Tickling, is a Confirmation of the Alliance there is between the Soul, and the Organs of Senſation. But, I am apt to imagine, that there is no Fact more ſingular, in reſpect of this reciprocal Correſpondence, than the Story recounted by St. *Auguſtine*. He tells us, that a certain Pariſh-Prieſt, named *Reſtitutus*, was poſſeſſed of a Soul ſo abſolutely Miſtreſs of the Senſes, that he could at pleaſure intirely deprive them of their Faculty of Feeling, and become like one dead. Tho' burnt, or pricked, he ſtill continued inſenſible. Nor was he apprized of having been pricked or burnt, but by the Marks that remained on the Skin. He could likewiſe intirely

The Touch. intirely suspend all manner of Sign of Respiration.

I have either read it somewhere, or have heard somebody strenuously assert it, that a certain Person, endued with a Faculty not unlike this, one Day in agreeable Company, having succeeded extremely well in dying thus voluntarily, over-acted his Part so far, as to forget to raise himself to Life again.

Sensation of Love. The Tickling, we have been just explaining, leads us naturally to another Kind of Sensation arising from the Touch, that is more perfect, more general, and essential to all Animals for the Propagation of their Species. This Sensation is a Sort of Taste for Immortality. The Sense properly called Taste, prompts us to take necessary Nourishment for the Preservation of Life; but this other Kind of Taste inflames us with a Desire of giving Being to others, and so to perpetuate our Race to the End of Ages.

Tho' this Sensation be only an extreme Delicacy of the Touch, which it possesses in common with all the Senses; it is nevertheless very distinct from simple Touching, and, indeed, much more so, than the Smell differs from the Taste. One may even confidently assert, that it has an undoubted Superiority over all the Senses, both by reason of its End, and of its Object, and the Nobleness of the Sensation itself. It is to this End all Beings endued with

Life

Life owe their Exiſtence. The Objects of all the other Senſes are material, foreign, Bodies; the Object of this Senſation is no leſs than another Senſation. It is an Organ full of Life and Spirits, that communicates them to another: Or rather, it is almoſt a general Commerce of all the Senſes, and principally of all the Kinds of the Senſe of Feeling. In reſpect of Senſation itſelf, if Love be put in Competition with the Appetite, we ſhall ſcarce perceive any Room for Compariſon. The latter, to a ſmall Pleaſure, joins a Mixture of Baſeneſs, conformable to Senſations worthy only of mere Brutes. To the former is attached a Senſation, that entitles it to the Name of Pleaſure, and that in an eminent Degree, connected with Affections that hold all Nature in the ſofteſt Chains; and the Sublimity and Delicacy of which is the moſt remarkable Characteriſtic of Human Nature, and the moſt valuable Property of the Heart and Soul. The Touch.

A Senſation, that is capable of being raiſed even to a Degree of Moral Purity, and ſublime Metaphyſics, might very well deſerve to be expreſsly treated of in a Work of this Nature, which has on other Accounts a Prerogative to diſcuſs Subjects of ſuch Sort; and, perhaps, this might not be the leaſt curious Province for real Naturaliſts. But there are ſo few of theſe, in reſpect of the prejudiced Part of Mankind, that, out of a Regard to the Infirmities of a

great

The Touch.

great Number of People, we will leave it to intelligent Persons to apply to this Sense Part of what we shall advance concerning the Taste, and other Senses, that have the most considerable Connexion with it.

Of

Of the TASTE.

THE TASTE, confidered fuperficially, would feem to be a Senfation peculiar to the Mouth, and diftinct from that of Hunger and Thirft. But, if we trace it to its Origin, we fhall be convinced, that this Organ, which in the Mouth makes us fenfible of the Delicacy of Meats and Drinks, is the felf-fame Principle, that in the Mouth, Gullet, and Stomach, is craving for Food, and incites us to a Longing after it. Thefe three Parts, properly fpeaking, are but one continued Organ, and have but one and the fame Object. If the Mouth creates in us an Averfion to any particular Food, does not the Gullet recoil at the Approach of it? And does not the Stomach immediately difcharge its difagreeable Contents? Hunger, Thirft, and Tafte are therefore three Effects of the fame Organ. Hunger and Thirft are the Motions of the Organ defirous of its Object. The Tafte is the Motion of the Organ in the Enjoyment of this Object: it being a Point paft all Conteft, that the Soul, united to the Organ, is the only real Subject of Senfation. This Unity of the Organ, in regard of Hunger, Thirft, and Tafte, is the Caufe of thefe three Effects being almoft ever in the fame

Proportion

The TASTE.

Proportion in the same Persons. The more violent the Appetite for Food is, the greater is the Enjoyment in Eating. The more the Taste is gratified, the more easily the Organs defray the Expence of this Gratification by Digestion. Because all these different Degrees, which I suppose the Result of a sound Habit, proceed from an Organ, that is more healthy, more perfect, and more robust. This Rule is general in regard of all the Sensations, and all the Passions. Genuine Desire constitutes the Proportion of the Pleasure, and of the Power; because the Power that gives Rise to the Pleasure, is also the Measure of it, just as the Pleasure is limited by the Desire of it. The more voracious the Stomach is, the greater Pleasure arises from Eating, and proportionably stronger is the Appetite. Without this mutual Consent, founded on the Mechanism of the Organ, our Sensations would destroy that Being, for whose Benefit they are established. A Gormandizer with a weak Stomach would die with Indigestion; while another Person with a voracious Stomach, but without Taste or Appetite, would, if it were possible, perish both by the Torment of his Voracity, and for want of proper Sustenance; which this Want of Appetite and Taste would deny him the Power of receiving, or digesting. In the mean while, how often is the digestive Power overcharged by the Appetite, especially in Men? because they do not follow the simple Motions of their Organs and Powers, as much

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as Brute Animals do: but, by indulging a lively Imagination, which is ſtill more fired by Artifices, confound the Harmony and Order, eſtabliſhed in Nature by it's Author. Let them therefore no longer condemn the Senſes, and Paſſions, to which they owe nothing but Gratitude; but aſcribe their Irregularities to an unbridled Imagination, and an Impotence of Reaſon, that has not Force ſufficient to reſtrain it.

The Taste.

The Taſte, in general, is the Motion of an Organ, that enjoys its Object, and is intirely ſenſible of its Goodneſs. It is for this Reaſon, that there ſubſiſts a Taſte in regard of all Senſation; Taſte for Muſick and Painting, as well as for what we eat or drink; as the Organ of theſe Senſations, if we may uſe the Expreſſion, has a Reliſh of theſe Objects.

Tho' the Taſte, ſtrictly taken, is common to the Mouth, Gullet, and Stomach, and there is ſuch a Sympathy between theſe three Organs, that what is diſagreeable to one, is generally repugnant to all; and tho' they are in a Sort of Combination to get rid of what is diſguſting; yet it muſt be confeſſed, that the Mouth poſſeſſes this Senſation in a more eminent Degree, and is endued with a greater Delicacy than the other two. A Bitter, that cauſes ſuch an Antipathy in the Mouth, as to create a Nauſea, will, in the Stomach, only prove a moderate Stimulus, juſt ſufficient to awaken its Faculties. It is very natural that the Mouth, which firſt

The TASTE. receives the Aliments, and of courſe becomes the Taſter, as it were, in reſpect of the other two, ſhould be endued with a diſcerning Property beyond them. It is the Part of a good Clerk of the Kitchen to diſtinguiſh himſelf by an elegant Choice of Proviſions, to prevent his incurring the Diſpleaſure of his Superiors.

This delicate Senſe is evidently the moſt eſſential of all the Senſes, after that of Feeling; and, indeed, more eſſential than the Touch, were not the Taſte itſelf a Sort of a more refined and ſubtil Touch. So that the Object of the Taſte is not a ſolid Body, as is that of the Touch; but they are Juices, or Moiſture, with which theſe Bodies are impregnated, or that are extracted from them.

The Mechaniſm of Savours. Theſe Juices, or Moiſtures, that make an Impreſſion on the Organ of Taſte, are called *Savours*. And ſometimes this Appellation is appropriated to their Impreſſion itſelf. The active Principles of Savours, or of ſavoury Bodies, are Salts, as well fixed as volatile. Earths, Phlegm, and Sulphurs are no Part of ſavoury Compoſitions, but ſerve to eſtabliſh a Variety; in the ſame manner as Shades, mixed with Light, form different Images. But at the ſame time theſe Shades make no Impreſſion on the Organ, that being intirely the Effect of Light. Thus Salts are the only Principle capable of affecting the Organ of Taſte. It is a Maxim univerſally known, that Water, Oil, and Earth have not

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the leaſt Taſte. Lymph then, or Water, is only the Vehicle of the Salts, diſſolving and conveying them; and their Mixture with Oil and Earth only makes them vary their Impreſſions a thouſand Ways. If to theſe Varieties be added thoſe, which reſult from the Nature of both ſimple and compounded Salts, the Variety of Savours will become an inexhauſtible Source. What a Variety of Images does Light produce with Shade alone! Again, what farther Variety ariſes from the blending of a few original Colours, and from Shade! Ought we to be leſs attentive to the Mixture of primitive Salts with one another, and with Water, Earth, and Sulphur? The TASTE.

Such is the Nature of Savours in general: now let us examine the Organ on which they act. Organ of Taſte.

The nervous Papillæ are here too the Organ of Senſation. All that is new in it is, that their Structure is a ſmall matter different from that of the Papillæ of the Skin, and that in Proportion to the Diſparity of their Objects. The Papillæ of the Skin, which are the Organs of the Touch, are ſmall, and of a compact fine Subſtance. They are covered with a Membrane ſufficiently ſmooth, and of a cloſe Texture. The Papillæ, that form the Organ of the Taſte, are much larger, more porous, and more open. They are moiſtened by a great deal of Lymph, and inveſted with a Skin, or incloſed in Sheaths, very unequal, and at the ſame time very porous.

The TASTE.

In Conſequence of this Structure, the ſavoury Particles are detained amidſt theſe Aſperities; diluted and diſſolved by a great Plenty of this Lymph, abſorbed by theſe Pores, and conveyed by the Aſſiſtance of this Lymph to the nervous Papillæ, where they make an Impreſſion by their ſtimulating Faculty.

Theſe Papillæ, the Organs of Taſte, are not only very numerous on the Tongue, but are beſides ſcattered here and there in the Mouth. We diſcover them, by Diſſection, to be diſperſed on the Palate, the inner Jaw, at the Root of the Mouth; and by Obſervation we are confirmed in our Opinion concerning their Uſe. Monſieur *de Juſſieu*, in the Memoirs of the Academy, relates the Story of a Girl born without a Tongue, who was not for all that deprived of Taſte. A Surgeon of *Saumur* ſaw a Boy of between eight and nine Years of Age, who in the Small-pox had intirely loſt his Tongue by a Gangrene, ſo that there remained not the leaſt Traces of one; and yet, notwithſtanding, he had a very diſtinct Taſte of whatever he put into his Mouth.

However, it muſt be confeſſed, that the Tongue is the principal Organ of this Senſation. Its Subſtance conſiſts of fleſhy Fibres, by means of which it aſſumes different Forms. Theſe Fibres are ſurrounded by, and interſperſed with an oily Subſtance, that renders the Compoſition more ſupple. Part of theſe fleſhy Fibres extend

extend themſelves beyond the Tongue, and are faſtened round about it, and form the exterior Muſcles that determine its Motion every way. This fibrous Body is incloſed in a Sort of Sheath, or very ſtrong Membrane.

The TASTE.

A Nerve of the ninth Pair, after its Ramification among the Fibres of the Tongue, is terminated on its Surface. The Ramifications of this Nerve, ſtripped of their firſt Coat, form the Papillæ we have been diſcourſing of. Theſe Strippings ſtrengthen the Covering of the Tongue, and contribute alſo to Senſation. The Papillæ, diveſted of their Coats, appear by their Figure of three diſtinct Claſſes; one of which reſembles a ſtanding Muſhroom, another Lentils, and the third ſhews itſelf in the Shape of Pyramids. The two firſt have a viſible Perforation in ſeveral Places, from whence oozes a limpid, watry Matter. All this Apparatus is ſhrouded by a very porous Cuticle, that diſtributes Sheaths to the nervous Papillæ.

The various Motions the Subſtance of the Tongue is ſuſceptible of, promote the Secretion of the Lymph which moiſtens the Papillæ, open the Pores that convey it to them, and determine the ſavoury Juices to enter them.

Difference of Savours.

When the Salts, that are introduced into the Pores of the Organ of Taſte, are whole and intire, and no ways ſoftened by any Mixture, they are violently pungent, and in Conſequence of that Pungency, obtain the Name of *Diſagreeable*; in-

The Taste.

asmuch as this Violence shocks the sensitive Substance. Of this kind are generally acrid, acid, salt Bodies, *&c.* when they are not mixed with any other.

When the Salts are sheathed by the oily or sulphurous Parts, so that their Edge is intirely blunted, and their Points even entangled in that manner that they can but very lightly irritate the nervous Papillæ, then this light Irritation produces a sweet *agreeable* Taste; as it excites in the sensitive Fluid that voluptuous Emotion, in which consists the very Essence of Pleasure. Such, ordinarily, is the Effect of Sugar, composed of salt and sulphurous Ingredients.

These are the two opposite Savours. Between these two Extremes, and even in each of these Extremes, arise innumerable Varieties.

I have just been asserting, that violent, acrid Savours are generally disagreeable; and that the Savours which do but, if I may be allowed the Expression, just tickle the Organ, are for the most Part agreeable: I must further add, that the Pleasure, or Disagreeableness, resulting from Savours requires them to exert a certain Degree of Violence or Tickling; and that a particular Disposition in the Imagination, on which the Impressions are made, must likewise necessarily concur to produce those Sensations.

All sweet or light Savours are not agreeable, nor all acrid disagreeable. Some Sweets are insipid: and there are acrid Substances which

are

are actually a Gratification to ſome peculiar Palates. And every now and then we meet with one, in whom the fineſt of Sugar ſhall cauſe Reachings. Imagination therefore bears a Part in the Senſe of Taſte, as well as in all other Senſations. As to my own Particular, how comes it to paſs, that I had formerly ſuch an Averſion to the Bitterneſs of Coffee, which now affords me no ſmall Regale? How came the firſt Oyſter that I ſwallowed, to create in me as much Nauſea as a Medicine, and by degrees to become one of my moſt delicious Repaſts? In the mean while, neither the Action of the Coffee, nor that of Oyſters upon my Organs is inverted; and the mechanical Diſpoſition of theſe Organs is alſo pretty much the ſame. All the Alteration therefore ariſes from the Part the Soul acts in the Affair, which does not form to itſelf the ſame Ideas on Occaſion of the ſame Impreſſions. There is then no Idea eſſentially annexed to ſuch, or ſuch Impreſſions: at leaſt there is no one which it is not in the Power of the Soul to alter. Hence ſome peculiar Diſhes are faſhionable in particular Countries; and what is the Delight of one Nation is often the Diſlike of another. Hence it is, in ſhort, that thro' Cuſtom we ſometimes transform that which at firſt is diſagreeable, into an Object of Pleaſure.

The TASTE.

Imagination bears a Part in the Senſe of Taſte.

Of the SMELL.

WE have in a former Treatise, placed Man in a State of Consciousness of his Existence: we have furnished him with the first Means of preserving his Being, by nourishing it: we have placed him at Table with a Taste and Appetite: but what Assurance can he have, that this Table that is served up to him, is spread with Aliments suitable to his particular Condition? He does not as yet enjoy the least Glimmerings of Light: and, if he did, his Eyes could not at all ascertain the Goodness of his Food, nor even perhaps demonstrate it was really Food, it being not their Province. Let us then procure him the Enjoyment of succulent and delicious Odours, that exhale from the Meats and Drinks that are prepared to regale him. Let us endue him with *Smell*. These odoriferous Particles have no sooner touched this Organ, than the Irritation immediately expands itself all over the Organ of Taste; and this being put upon the Scent, furnishes in an Instant every Machine requisite for seizing the Prey.

I imagine therefore, that the Smell is not so much a particular Sense, as a Part of, and Supplement to, that of the Taste, to which in a manner it stands Centinel. In a word, the Smell is

is the Taſte of Odours, and as it were the Anticipation of ſavoury Bodies. The Membrane, which lines the Noſe, and is the Organ of this Senſation, is a Continuation of that which lines the Throat, the Mouth, Gullet and Stomach: and the Difference, in regard of the Senſations of theſe Parts, is pretty nigh in Proportion to their Diſtance from the Brain. That is to ſay, the Smell differs no more from the Taſte, than the Taſte does from Hunger and Thirſt. The Mouth is endued with a finer Senſation than either the Gullet or Stomach; and the Noſe enjoys one ſtill more delicate than the Mouth, by reaſon it is nearer to the Source of Senſation. And, again, all the Filaments of its Nerves, and of their Papillæ, are fine, hollow, and full of Spirits. Whereas thoſe that are diſtant from this Origin, acquire, thro' the natural Tendency of the Nerves, a greater Solidity, and become thicker coated, their Papillæ degenerating into a kind of Excreſcence: Now all the World knows, that Excreſcences are not endued with any great Degree of feeling. The SMELL.

Nobody is ignorant that the Inſide of the Noſe is the Organ of the Smell; but very few have a juſt Notion of the Mechaniſm with which this Inſide is contrived in order to receive this Senſation *.

Immediately after the Opening of the Noſtrils, which is ſufficiently ſtrait, the Inſide of the Mechaniſm of the Organ of Smelling.

* Conſult the Figure annexed.

The Smell. the Nose forms two Cavities, which are ever separated by one Partition. These Cavities are enlarged in Proportion to their Distance from their first Entrance; and they are again united in one intire Cavity, that extends itself even to the Bottom of the Throat, by which means they have a Communication with the Mouth.

All this Cavity is lined by the Pituitary Membrane, so stiled by the Ancients, by reason of the Phlegm that is continually flowing thro' it. This Membrane is of a spongy Nature, and has on its Surface an exceeding soft and short Down. The spongy Texture is formed by Vessels and Nerves, that are interwoven with a great Number of Glands. The Down is composed of the Extremities of these Vessels, to wit, of the small nervous Papillæ that constitute the Organ of Smelling, and of the Extremities of the Vessels thro' which flows the Phlegm, and the Mucus of the Nose. These Liquids lubricate the nervous Papillæ, and render them fit for discharging their Function; and are farther assisted in this Office by the Tears, which the lachrymal Canal conveys along the Nose.

The olfactory Nerve, the first Pair of Nerves that proceed from the Scull, is that which spreads itself in the Pituitary Membrane. Its Filaments are in great Number, seem to be softer, and are more visible than in any other Organ.

This

This Structure of the Nerves, ſubſervient to the Smell, whoſe Efficacy depends on the near Connexion they have with the Brain, renders them ſtill more ſuſceptible of receiving the Impreſſion made by odoriferous Bodies. The SMELL.

The great Number of Filaments that conſtitute the Olfactory Nerve, is what produces the numerous Glands in the pituitary Membrane; theſe Glands being nothing elſe than the Extremities of the Nerves expanded about the Papillæ.

Beſides the Olfactory Nerve, there enters the Noſe a Branch of the Opthalmic, that is to ſay, of one of the Nerves of the Eye. It is the Communication of this ſmall Nerve with that of the Smell, which is the Cauſe that we ſhed Tears on Occaſion of any ſtrong Scents, and ſneeze at the Rays of the Sun being directly darted on our Eyes: becauſe this ſmall Nerve, in its Origin, is connected with the Nerves diſtributed in the Organs of Reſpiration. So that on any quick Irritation, it excites in theſe Organs thoſe convulſive Motions, from whence reſults Sneezing. Strong Odours make us weep, and ſtrong Rays of Light ſneeze.

The downy Coat of the Pituitary Membrane is intirely proper for imbibing the odoriferous Fumes: but there is ſtill another Contrivance for fixing theſe Particles on their proper Organ. The Inſide of the Noſe is furniſhed on each hand with two Sorts of complicated Windings, which advance very far in this Cavity, cauſe a

The SMELL. Sort of Obstruction in the Passage of it, and oblige by that means the odoriferous Vapours to diffuse themselves, and to stop a limited while within their Capacity.

This Structure determines these Vapours to act a longer Time, in a stronger Manner, and on a larger Extent of the Pituitary Membrane; and, consequently, the Sensation resulting from thence is rendered the more perfect. For this Reason, Dogs of the Hunting Kind, and other Animals that are remarkably distinguished for the Perfection of their Smell, have these winding Cavities in their Noses considerably larger than Mankind have.

These same Windings, in stopping a little the Air respired thro' the Nose, soften the Rigour of it in Winter. And it is this good Office which they render the Lungs, that exposes the Pituitary Membrane to the greatest Share of those Obstructions called Rheums, and Defluxions of the Head. In these Disorders, the mere Swelling of this Membrane shuts up the Passage of the Air; because the Coats of the Fibres being grown thicker, immediately close. Which is a Demonstration, that altho' the Cavity of the Nose be very considerable, the Labyrinth, notwithstanding, that Nature has established in its Mechanism, in order to the tasting, if the Expression be allowable, of Odours, leaves but a very small Portion of empty Space.

The

The odoriferous Fumes, which conſtitute the Object of the Smell, are in reſpect of a Fluid, what ſavoury Bodies are in regard of Liquids and Juices. A Salt is ever the Agent, or at leaſt the Inſtrument and Stimulus of the Senſation. All Salts without diſtinction produce Taſtes; but they muſt be volatile, to affect the Organ of the Smell. Aqueous, ſulphurous, *&c.* Vapours, diſſolve, convey, modify the Impreſſion of Salts, and concur to diverſify the Scents. In a Word, all that I have delivered on the Subject of Taſtes, is exactly applicable to the volatile Fluidity of odoriferous Bodies.

The SMELL. Mechaniſm of Odours.

The prodigious Quantity of theſe volatile Fluids, exhaling inceſſantly from an odoriferous Subſtance, and that without any ſenſible Diminution of its Weight, is a Proof, that Matter may be divided in an aſtoniſhing manner.

The general Vehicle of theſe ſcented Corpuſcles is the Air. Theſe little Bodies are diffuſed in the Atmoſphere, and are there ſuſtained: either becauſe they form a ſubtil Fluid, as light as, or lighter than, Air; in which of courſe they muſt remain in an Equilibrium, or riſe according to the Laws of Hydroſtatics; or theſe Corpuſcles, tho' heavier than Air, yet fly upwards in this Fluid, by reaſon of the great Velocity with which they are ejected from the odoriferous Body, and by the Velocity of the Air itſelf, which concurs to bear them aloft. As a Horſe on full Speed, and the Wind to-

Vehicle of Odours.

The SMELL. gether, raiſe a Cloud of Duſt much heavier than the Air in which it floats.

It is not ſufficient that the Air be in a manner impregnated with odoriferous Particles; it is likewiſe neceſſary that they be conveyed to the Cavities of the Noſe, which is the natural Conſequence of Reſpiration. This obliges the Air to paſs and repaſs inceſſantly thro' theſe Cavities, in order to its Entrance into the Lungs, or its Departure from thence. For this Reaſon, thoſe that have the Paſſage of their Noſe obſtructed by a Catarrh, and ſo are under a Neceſſity of reſpiring by the Mouth, are deprived at the ſame time of the Faculty of Smelling. Monſieur *De la Hire* the younger once ſaw a Perſon who prevented his being ſenſible of any diſagreeable Scents, by raiſing up his Uvula, ſo as to cut off all Communication of the Noſe with the Mouth; whence he reſpired for the future this latter Way *.

This ſame Paſſage of the Air thro' the Cavities of the Noſe, ſerves ſometimes to cleanſe them from Obſtructions; as when it is forced violently from the Lungs, either in blowing the Noſe, or by ſneezing.

Effects of Odours. There is not only a Gratification, or elſe a Diſagreeableneſs in Odours, as there is in Taſtes; but they likewiſe ſupport the languid Powers, by ſtimulating the Nerves, and recruiting them with a freſh Supply of Spirits. They ſometimes

* Obſerv. Phyſiq. Tom. *II.* Pag. 103.

The SMELL.

ſometimes alſo diſconcert the ſame Nerves, put them into Convulſions, and produce Vapours and Swoonings, when they make a diſpleaſing Impreſſion. The Imagination, as to this Point, is not ſtripped one Jot of the Rights we have eſtabliſhed in it, over all the Senſes. Whence is it, that Muſk, ſo favourite a Perfume formerly, ſhould at this time o' Day be a general Source of vapouriſh Diſorders in the fair Sex, and even ſome few of the Men: whereas Tobacco, of an ammoniacal and venomous Flavour, conveys one of the moſt delicate, the moſt delightful Smells in Nature? Is it becauſe there is an Alteration in the Organs? No! It is Habit, Prejudice, Imagination.

Imagination bears a Part.

Singular Perfection of the Smell. Its Cauſes.

Mankind, ordinarily ſpeaking, have not the Senſe of Smelling to that Perfection which Brute Creatures have, the Reaſon for which Difference we have accounted for. The Rule notwithſtanding is not abſolutely general. There are Negroes in the *Antilles* Iſlands, who like Dogs follow their Maſters by the Print of their Feet, and diſtinguiſh by their Noſe the Track of a Negroe from that of a *Frenchman* *.

Strange Relation of Sir *Kenelm Digby.*

If any Credit may be given to Sir *Kenelm Digby*, a Boy, whom his Parents had brought up in a Foreſt, (whither they had fled to avoid the Calamities of War) and who had lived on nothing but Roots, had a Smell ſo delicate, that

* Obſerv. Phyſiq. Tom. II. Pag. 103.

The Smell. that by this Senſe he perceived the Approach of the Enemy, and apprized his Parents of their coming. He was in the mean while made Priſoner; and, having altered his Method of living, in length of Time he loſt much of that ſurprizing Delicacy of Smell. However, he was not intirely deprived of this ſingular Faculty. For being married, he could very eaſily by ſmelling diſtinguiſh his own Wife from another Woman, and even find her out by the Print of her Foot, as a Dog does his Maſter. A Huſband of this kind would in *Italy* make an *Argus* ſtill more terrible than the famous one in the Fable.

It ſeems then, that the Perfection of the Smell, in Brute Animals, not only depends on the Organ, but likewiſe on the manner of living, and on the Privation of thoſe ſtrong Odours, with which Mankind are conſtantly ſurrounded, and to which their Organs are ſo much accuſtomed, that Scents ſo weak and ſo ſubtile, as thoſe we have been ſpeaking of, cannot make the leaſt Impreſſion on them.

Monk of *Prague*. The Monk of *Prague*, mentioned in the *Journal of the Learned* of the Year 1684, is ſtill a more extraordinary Caſe, than the preceding. He not only knew different Perſons by the Smell; but, what is much more ſingular, could, we are told, diſtinguiſh a chaſte Woman, married or unmarried, from one that was not ſo.

ſo. This Religious had begun to write a new Treatiſe on Odours, when he died, very much lamented by the Gentlemen who record this Story of him. For my Part, I do not know whether a Man of ſuch Talents would not have been dangerous to Society.

The SMELL.

Of the HEARING.

OUR Perfections increase insensibly. In the first Place we were assured by the Touch of the Solidity of Bodies, and their principal Properties in regard of us. Then we discovered the very Motion of the Juices and Liquids, with which some of these Bodies are impregnated, and even the Fumes that exhale from their Substances. In short, we have been made sensible both of the grosser and the more subtile Parts of most Bodies, that are within our Reach and Contact. This limited Commerce might absolutely be sufficient for us; and, in effect, is sufficient for a few, that are said to be ill-treated by Nature; because her Liberality has been more beneficent to us, and extended our Communication with other Beings far beyond those that surround us, by the *Hearing*, and even far beyond the World we live in, by the *Sight*.

This Communication is ever established by the Matter that affects an Organ: but, in Proportion as this Matter advances, it becomes more and more subtile, is more and more expanded at a Distance, and more and more capable of bringing us Tidings from a-far, that are altogether foreign to our Atmosphere.

We

The Hearing.

We are now on the Point of tranſcending the Bounds of this Atmoſphere. For the Object of Hearing is Noiſe in general. Now Noiſe conſiſts in a quick Vibration of the Air, communicated to the very Organ of this Senſation; and this Communication, it is very well known, is ſet on Foot at a great Diſtance.

The Noiſe, which renders the Vibrations of the Air fuller, more regular, and, conſequently, more pleaſing to the Ear, is called *Sound.*

The Vibrations of Sound, in producing an agreeable Surprize, have excited Men's Curioſity and Induſtry, to form them into an Art adapted to pleaſe and move them, by the Senſe of Hearing. All the Senſes have been equally productive of Arts to gratify, or perfect, or to guard themſelves from bad Impreſſions. What Arts has not the Senſe of Feeling produced? Theſe Garbs, magnificent Houſes, gilded Chariots, are all the Effect of Delicacy. If the Ear has its *Lulli's*, the Mouth is not without its *Martialot's*, nor the Eye its *Galileo's*, &c. All of them valuable in their Way, becauſe they have applied themſelves to the Improvement of Human Nature. Let us now examine, as Philoſophers, ſome of the Principles of ſimple Sound, and of Sound reduced to an Art.

The Hearing.

The Mechanism *of* Sounds.

SOUND is, in the ſonorous Body that produces it, the ſame it is in the Air itſelf that conveys it to the Ear; *viz.* the ſhaking of a Body, put into Motion by the Impulſe of ſome other. Such is a Bell ſtruck by its Clapper; a Violin ſhook by its Strings, which the Bow ſets a trembling; a Flute agitated by the Impulſe of the Air againſt its Embouchûre.

The Air that produces Sound is not common Air.

It is a Miſtake to imagine that the Air, put into Motion by ſonorous Bodies, is this groſs and palpable Air, which we fan with our Hat, and blow the Fire with. The Sound of the largeſt Bell does not communicate the leaſt Motion to the Flame of a Candle: whereas the leaſt Breath of Wind, that is to ſay, the ſmalleſt Motion of groſs Air, gives it a Tremor, and extinguiſhes it.

The Air therefore, that produces Sound, as it is proportioned to the Organ of Hearing, is much more ſubtile than common Air.

Motion of ſonorous Bodies for Sounds.

The Motion of a ſonorous Body is compounded of two others, namely, of the trembling of all the ſmall Parts that compoſe this Body, and the vibrating Motion reſulting from the whole.

In Conſequence of the firſt Motion, or Trembling, the Particles of the Body approach to, and retire alternatively from, one another with

a prodigious Velocity; whence their refpective Situation and the Figure of their Pores change without ceafing. The Hearing.

In the Vibration of the whole Body, there falls out amongft the Surfaces of the Body, what we have been juft obferving to happen amongft the Particles concerned in the Trembling: For Inftance, a Bell, when it founds, from being round, becomes oval; and fo, *vice verfâ*, Millions of Times in a Moment. A String likewife, tho' ftrait, and extended upon the Bridge, from it's natural Straitnefs is curved here and there an Infinity of Times, in a very little Space.

Principles of Tones and Accords.

Both the one and the other Motion produce Sound; and the Duration of the Vibrations, as well of the intire Body, as of its Parts, determines the Species of Sound, flat, or fharp. For Example, a long String, or a fmall flack one, or one formed of Matter very little elaftic, gives a flat Tone; becaufe the Vibrations of a String of that Kind are flow, grand, and at a Diftance from one another. On the contrary, a String wound up high, or made of Matter endued with great Elafticity, produces a fharp Sound, by reafon its Vibrations are fhort, quick, and clofe. Suppofing therefore two Strings of the fame Matter, of the fame Size, and equally extended, and one of which is the Moiety of the other, that which is but the Moiety, will found the Octave of the other; becaufe its Vibrations are as fhort again, and equivalent to

The Hearing.

thoſe of the other. Theſe Octaves are attended with an harmonious Effect, as, from the double Vibrations, made by the ſmall String, one of them is ever falling in with the Vibrations of the larger; whereby they concur to render the ſonorous Vibrations more compleat, put a greater Quantity of Air in Motion, and are conſequently more agreeable. This is the Principle of all muſical Harmony, and particularly the Mechaniſm of playing on the Violin, and of all Inſtruments whoſe Tones are produced by the ſhortning of the Strings, in Conſequence of the Diſpoſition of the Fingers. The more Vibrations there are that concur, the more perfect is the Harmony. On which account the Uniſon is the firſt and compleateſt of all this Claſs of Sounds, or rather, is of itſelf true and perfect Muſick: becauſe, in this State of the Strings, all their Vibrations are in Concord, and always ſtrike the Air together. Diſcordant Tones are thoſe, where there are no concurring Vibrations.

In Conſequence of this Equality and Regularity of Vibrations in the Uniſon, when the String of an Inſtrument is touched over againſt another that has a String wound up in the ſame manner, this latter String is agitated by the Sound of the former; becauſe this String, being in the ſame State, and diſpoſed for the Uniſon, falls in with the Vibrations of the Air, whoſe Returns are conformable to the Length and Tightneſs of it, and, in ſhort, to the Vibrations that reſult from

it: whereas the Motion of the other Strings, whoſe Vibrations are diſcordant, is ſoon interrupted, and ſuppreſſed by thoſe very Vibrations of the Air, that are inſtantly making their Efforts to excite Vibrations in it. To have a clear Conception of this Conſonance, and of its Defect, ſuſpend a Ball on a Thread, and poize this Ball in the Air, giving it a Puſh with your Finger. If you have a Mind to carry on the Vibrations of this Ball, you muſt accommodate yourſelf to it, and be careful to puſh it at the End of every Vibration, when it is on the Point of beginning another. Thus may you continue theſe Vibrations as long as you pleaſe, and be in the Caſe of the String in the State of Uniſon with another. But ſhould you, in Contradiction to the Vibrations of your Ball, go abruptly to touch it in the Middle of its Career, you will ſtop the Ball. And this is what the Air does, that is ſhook by a String, in regard of the other Strings with which it bears no manner of Conſonance, in Oppoſition to all Uniſon. The Hearing.

This is the Principle of the Difference of Tones, and harmonious Accords. As to the Force of Sound, this depends on the Quantity of Air, put in Motion by the ſonorous Body; and this Quantity depends either on the Force of the Vibrations of the ſonorous Body, or on its Extent. A Perſon in the ſame Key, and of the ſame Bulk of Voice, will ſooth the Ear by moderating the Impulſe of the Air in his Or-

The Hearing.

gan, and be able at the ſame Time to ſtun one by exciting more violent Vibrations. But ſhould he multiply theſe Vibrations by a vaſtly high raiſed Voice, or by an Inſtrument that puts a great deal of Air in Motion at once, his Voice will then produce a Noiſe, that will almoſt be inſupportable, and carried to a great Diſtance. Theſe Principles are very applicable to the Trumpet, French-Horn, and to other loud-ſounding Inſtruments; becauſe they agitate a large Quantity of Air, and agitate it violently, by reaſon of the great Elaſticity of the Matter of which they are compoſed.

This I have been diſcourſing of has been long known to the World: But our Moderns have enriched the Subject with freſh Diſcoveries, and intirely new Hypotheſes.

On touching two Strings of a Violin at once, that are tuned to a Fifth, one may perfectly hear the Sound of both. In the mean Time, one of theſe Sounds conſiſts in a double Vibration of the Air, and the other in a triple. But the ſame Maſs of Air cannot produce at one and the ſame Time three Vibrations of one Part, and two of the other, and thoſe diſtinct from one another. If you throw two Stones at once into a Lake, hard by each other, the Undulations they will form in the Water, will either be confounded in one alone, or be mutually deſtroyed. For the ſame Liquid is not ſuſceptible of two or more different Vibrations at once.

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The contrary is, however, the Case, in the Fluid that produces Sound, which receives at once the Impression, not only of two, but of all the different Tones of Musick, and conveys them distinctly to the Ear. It is necessary then that the Air, which generates Sound, be composed of several Species of Fluid, more or less subtile, each of them endued with a Property of producing the Vibrations, or the different Tones, of *Ut*, *Re*, *Mi*, *&c.* much after the Manner as Light is formed of several Kinds of Rays adapted to the Production of Red, Yellow, Green, Blue, *&c.*

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Species of Air productive of Tones, compared to original Colours.

Supposing this to be Fact, one may easily conceive, that each Tone will affect its own peculiar Fluid, or that whose particular Vibrations constitute this Tone; by which means the Ear is capable of receiving at once all the Impressions of each of these Fluids, and of every one of these Tones, as the Eye receives at once the Impulse of several Colours.

On touching only one String of an Instrument, the Generality of Mankind are sensible but of a single Tone: whereas those that are versed in, and accustomed to, Musick, distinguish, besides this fundamental Tone, the Octave, the Fifth, and the Tierce, absorbed in the principal Tone. From hence chiefly results all Harmony.

Now by the Principle of shortening the String, which we have been speaking of, the

Octave

The Hearing.

Octave is the Moiety of the Fundamental Sound, or the Product of half of the String; the Fifth is the Product of two thirds of the ſame String; and the Tierce the Product of four fifths of it.

It is Matter of Fact, ſay the Journaliſts of *Trevoux*, that the Parts of an extended String, are extended unequally from each End to the Middle. The Trembling alone of the String makes a natural Diviſion of it: for which Reaſon one may imagine, that the middle Part of it, being leſs extended, produces the total Sound; and that the other Portions will make a Tierce, a Fifth, and an Octave, as they approach the Ends of the String, according to the Order I have been recounting.

It would be better, in my Opinion, to apply here the Species of aerial Fluids proper to each Tone; and, by purſuing the Compariſon of Tones with Light, to ſay, that the intire String agitates at once every Kind of Fluid; and that this Combination of Vibrations produces the fundamental Sound, as, in regard of Light, White, compounded of all Sorts of Rays, eſtabliſhes the fundamental Colour; and that we in general do not at all diſtinguiſh in this fundamental Sound the other Tones that compoſe it, any more than we perceive the various Kinds of Rays in White; but that the Ear of an excellent Muſician is a Sort of Priſm, that ſeparates or diſtinguiſhes the Tones thus confuſed.

This

The Hearing.

This Perfection of the Ear, ſuperior to that of the Eyes, will be no ways aſtoniſhing to thoſe who have ever remarked, that this Senſe is more compleat in its Kind, than Viſion is. For, without going any farther, the Hearing abſolutely diſtinguiſhes all the Gradations of Sounds, determines them, reduces them to Calculation, and actually forms them into an Art. The Eyes cannot boaſt ſo much in reſpect of Light. They perceive in the Lump, that a luminous Body, a Colour, is more or leſs clear, or more or leſs deep, than another; and that is all. But the Quantity of this more or leſs they never will be able to determine.

I ſhall now mention another Singularity of Sound rendered by Strings.

New fluted Sounds.

We have ſeen that the Moiety of an intire String ſounds an Octave; and that likewiſe, on applying the Finger to the Middle of a String, this Octave will be produced in any Part of it touched by the Bow.

If, inſtead of reſting the Finger firmly on the String, and the Neck of the Inſtrument, one touches the former but lightly, either with the Finger, or only with a Quieter, the Octave will be the ſame, as by applying the Finger hard, and even a more agreeable one: becauſe both Parts of the String contribute to it at once, and the intire String touched never ſo gently, or if one ceaſes from Time to Time to touch it at all, mixes with it a little of the fundamental Sound.

Conſe-

The Hearing

Conſequently, it is juſt as if one touched three Strings at a Time, in a State of Uniſon, which cannot fail of producing an harmonious Tone.

The Reaſon of this Singularity in Muſick, is, becauſe the ſimple Touch of the Quieter makes a Sort of Diviſion of the String into two equal Parts. It is a ſmall moveable Bridge, that ſeparates the Vibrations of each Portion of the String, without interrupting in the mean while the Communication of theſe Vibrations. The String trembles under the Quieter; but the Vibrations of the intire String are thereby ſhortened, or, if you will, the firſt Claſs of ample and compleat Vibrations, which form the fundamental Sound, are ſuppreſſed, the String being only affected by the ſubaltern Vibrations of the Octave. What I here advance is in Suppoſition, that the Vibration of the fundamental Sound includes all the other Vibrations, which is really Fact. For when the Quieter touches the Middle of a String, you may make a double Octave ſound on this String, without removing the Quieter from its Place. In order to this, firſt ſcrape ſtrongly with your Bow, and you will give the String its fundamental Tone: becauſe then the Force of the ample Vibrations, which form this Tone, ſurpaſſes the Touch of the Quieter, and renders it ineffectual. Secondly, puſh the Bow with leſs Violence, and you will ſound an Octave, as we have intimated: becauſe in that Caſe the Quieter ſuppreſſes one of the Claſſes of

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the Vibrations; or becaufe the Vibrations, being too feeble, lofe againft this Quieter one of their Claffes, or a Moiety of their Quantity. The different Degrees of this Quantity, contained in the Vibration of a flat Tone, would they not be the firft Caufe of that Harmony, which Muficians diftinguifh in the fole fundamental Tone? The Juftnefs of this Explication appears confirmed by this other Experiment.

If you place your Finger to a Tierce of the String, and there reft it firm, it is evident you will found a Fifth. But, if you there apply the Quieter, you will found a Twelfth, or the Octave of a Fifth. Now if you reft your Finger afrefh on this Place, and pafs the Bow upon this Tierce of the String towards the Neck of the Violin, you will produce the fame Sound, the fame Twelfth, as refulted from the Quieter, when you paffed the Bow upon the two other Tierces of the String. It is therefore the Sound of this Tierce of the String which you hear, when the Bow paffes upon the two other Tierces. The Vibration of the Bow then paffes from the two Tierces, which it touches, to the Tierce which is beyond the Quieter. This Quieter therefore does not at all intercept the Vibrations of the String: it makes only a Sort of Divifion, or Subdivifion, on each Part of it. But what is the Reafon that the Bow, which paffes over two Tierces of the String, does not rather caufe the Sound of this long Portion to affect the Ear,

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Ear, than that of the Tierce, over which it passes not at all? It is absolutely because this Tierce is shorter, that the Ear is rather affected by its Vibrations. These being shorter produce a sharper Tone. Now a sharp Tone is ever predominant over a Flat, and drowns it intirely.

The more you move the Quieter, either towards the Neck, or towards the Bridge, the sharper is the Tone; because it is ever the Tone of the short Portion of the String that strikes our Ears.

These Sounds are termed Fluted Sounds. Monsieur *Mondonville* calls them harmonious Sounds; and was the first who had the Courage to introduce them into grand Pieces, and the Address to make their Execution agreeable to the public Taste. We name these Sounds *Fluted*, because they have the soft and melodious Tone of the Flute. But they merit likewise this Appellation, inasmuch as they transfer to the Violin the Mechanism of the Flute; on which, it is well known, the same Hole is productive of several Octaves.

How quick soever the Vibrations of the Air are, that is put in Motion by the Body which produces Sound or Noise, they still take up a certain Time to communicate themselves, one after another, to the Air that is at a Distance from the Body which excites them. The Reason of this Delay is, because the Air, being elastic and porous, that which surrounds the sonorous

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norus Body gives way to the Preſſure of this Body, and catches, if I may ſo expreſs myſelf, in its Pores the Enlargement of it. This Air dilates itſelf afterwards in its Turn a little beyond its natural State, agreeably to the Diſpoſition of all elaſtic Bodies. By this Means it communicates the Preſſure it had juſt received to the Column of Air at a Diſtance: which Column of Air being confined, and afterwards enlarged in its Turn, acts in like manner, in regard of the ſubſequent Column, and ſo on ſucceſſively. But this Succeſſion of Preſſure and Enlargement, from Column to Column, demands a certain Time.

One is convinced of this Truth on ſeeing a Gun diſcharged on a remote Plain. The Report of it does not reach the Ear, until a long Time after the Eyes have diſcerned the Flaſh. But it has been determined by exact Experiments, how much Time, Sound, or Noiſe, takes up in communicating itſelf ſucceſſively, or what Way it makes in a given Time: and by the laſt of theſe Experiments, made by the Gentlemen of the Academy of Sciences, at the fartheſt Diſtances, it has been found *,

Firſt, that the Report of a Cannon is propagated three Hundred and forty ſix Yards in a Second, and of courſe twenty Thouſand ſeven Hundred and ſixty Yards in a Minute. A League

* *Mercure de* Juin 1738. *Extrait d'un Mémoire ſur la Propagation du Son, par Mr.* de Caſſini de Thury.

The Hearing. League being four Thousand five Hundred and Sixty four Yards, the Sound is conveyed every Minute four Leagues and a half, and two Hundred and thirty Yards. Consequently, it travels in an Hour two Hundred and seventy three Leagues, and one Hundred and eight Yards.

Secondly, that Sound is transmitted with the same Velocity, when it traverses a great Space, as when it runs over a smaller, without any Diminution.

Thirdly, that Sound is transmitted with the same Velocity in the Day-time as in the Night.

Fourthly, that there is likewise the same Velocity in rainy Weather, as when the Sky is serene.

Fifthly, that the Swiftness of Sound is equal, both when the Noise that produces it is great, and when it is small; when the Mouth of a Cannon, for Example, is directed towards the Place, from whence the Report is made, and when it is pointed in a contrary Direction.

Sixthly, that the Velocity of Sound increases when the Wind sets fair for it, and diminishes when it is contrary, in Proportion to the Force of the Wind.

When the Vibrations of the Air, that produce Sound, strike a Body of a certain Extension, they are reflected from under that Body to a particular Point, by preserving their Modulation in such a Manner, that the same Vibrations

The
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The Organ of hearing on the right Side

are there repeated, tho' more languidly. This Repetition, or Reflexion of Sound, is called an *Echo*. The Hearing.

Several Echoes will reſult from a Place, when there are ſeveral Bodies at different Diſtances, that reflect the Sound towards the ſame Spot. The Reflexion of Sound, is governed almoſt by the ſame Laws, as the Reflexion of Light, which we ſhall ſpeak of in its Place. There is no Neceſſity for the reflecting Body being concave. A ſingle Wall will produce an Echo: and I myſelf have known them rendered by convex Bodies, as well as by thoſe of great Turnings and Windings.

Reflexion of Sound, termed an Echo.

The Organ *and* Mechaniſm *of* HEARING.

IN vain does the Air, agitated by ſonorous Bodies, give us Shocks from all Quarters, if we are not furniſhed with particular Organs to receive its Impreſſion. The Wind is felt by the Touch; but the Portion of Air that produces Sound, is of too ſubtile a Nature to affect this groſs Senſe, on which it makes not the leaſt Impreſſion.

The Ear is the Organ appropriated to this Senſation. I obſerved above, on the exterior Part of it, a Sort of Tunnel, like the broad End of a Trumpet, very well adapted to the collecting a great Quantity of Air. This Tunnel is much larger in certain Animals, as in the Aſs

The Hearing. the Hare. It is accommodated with Muscles that shut and open it on hearing, on which account these Animals have this Sense to a great Perfection. Man has also auricular Muscles, but they are of little Use for Want of Habit. There are those notwithstanding, who have the Motion of these Muscles no less than Animals; such, for Instance, was the celebrated Monsieur *Mery* *.

The Membrana Tympani. This exterior Tunnel is attended by a Canal ending in a Membrane, that is as it were the first Entry to the auditory Sinus's. This Membrane is stretched like the Head of a Drum, from whence it has obtained its Name. Its Centre sinks a little towards the first Sinus that is behind, and which is called the Tympanum, or Drum of the Ear. In this Sinus are a Sort of Springs or little Pullies, which terminate at one End in the Center of this Membrane, and at the other in the Entrance into the second Sinus, and are put in Action by Muscles. This Membrane and its Springs appear to have, in respect of the Hearing, the same Use, as the Pupil seems to have in Regard of the Eye. The Pupil is contracted or dilated in order to receive an Image in the greatest Perfection, and without the least Injury to the Organ. The Membrane of the Tympanum is extended or relaxed like-

The Tympanum, or Drum of the Ear.

wise

* A famous Surgeon of the Hotel-Dieu at *Paris*, and a Member of the Royal Academy of Sciences.

wiſe, to tranſmit to the Hearing the moſt perfect Vibrations, and ſuch as are proportioned to this Organ. When the Ear is aſſaulted by the Impulſe of too violent a Sound, this Membrane, whoſe Center is ſunk towards its Sinus, is puſhed outwardly by the Spring which terminates in its Center. By this Mechaniſm this Membrane is relaxed; which Relaxation diminiſhes ſo much of the Impetuoſity of the Sound, as might be capable of hurting the Organ. At the ſame Time, and in Conſequence of the ſame Motion, the Spring oppoſite to this, cloſes the Entrance of the ſecond Sinus, and weakens alſo by that means the Impulſe of the Air in this ſecond Sinus. The Hearing.

On the contrary, when the Sound is too feeble, the firſt Spring draws the Membrane of the Tympanum inwards, and renders it more extended, and more ſuſceptible of Agitation; the other opens the ſecond Sinus, and facilitates the Action of the Undulations of the inner Air.

In Sounds, that are a Medium between the two preceding Extremes, the Membrane of the Tympanum likewiſe preſerves a middle Tenſion; by which Conduct it is proportioned to theſe Sounds, and as it were in a State of Uniſon with the Vibrations of the Air. Hence the trembling of this Membrane communicates the Sound to the inner Part of the Organ, in a manner more compleat and perfect. As the Pupil,

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in a just Degree of Dilatation, transmits to the Retina a clear and distinct Image.

The first Spring destined to extend and relax the Membrane of the Tympanum, is composed of the little Bones called the *Malleus* and *Incus* *, or the Hammer and Anvil: the second is formed of the same *Incus* and the *Stapes*, or Stirrup, joined together by the *Os Orbiculare*; and the Basis of the *Stapes* makes the Entry to the second Sinus. It is possible, that the Justness of the Ear in Musick depends partly on the Regularity of the Motion of the Muscles of these little Bones, in order to dispose exactly and readily the Membrane of the Tympanum to a Unison of the Tones it receives. One sometimes discovers in this Membrane a little Chink detected first by *Rivinus*.

Mistake of some Anatomists concerning Apes.

We read in the third Tome of *Observations de Physique*, p. 278, that, as Anatomists remark, Apes have not in the Ear the three small Bones we are speaking of. But I can assure the Public, that this is a Mistake. I have dissected a *Sapajou* Ape, and actually met with the Bones in Question. It is true, indeed, that they were in a manner hid, and sunk down towards the Sinus of the mastoid Apophysis; which is, perhaps, what has deceived those Anatomists.

Nevertheless, I do not at all assert, that the Membrane of the Tympanum, and those Bones are

* Consult the Figures.

are abſolutely neceſſary for hearing, but for the Juſtneſs and Perfection of it. This Membrane is alſo ſubſervient to the preſerving the Inſide of the Ear from the Injuries of the Air, and exteriour Bodies. The Neceſſity of theſe Organs is evinced from Experience. On breaking the Membrane of the Tympanum of a Couple of Dogs *, thoſe Animals heard well in Appearance, but became deaf a little while after. The Hearing.

Theſe little Bones of the Ear acquire no manner of Accretion, being of equal Size in Infants as in Adults; becauſe, perhaps, they are extremely hard, and detached from all others, and the Membrane that inveſts them is ſo thin, that one of the greateſt Anatomiſts of the Age imagined they had no Membrane at all.

Inner Air of the Ear.

The firſt Cavity of the Ear contains, beſides theſe Machines, a ſubtile Air, which it receives from the Bottom of the Throat, by a Canal, called *Euſtachius*'s Tube †, the broad Part of which opens itſelf towards the Place of the Communication of the Noſe with the Mouth. It is by this Paſſage of the Air, and the Perforation obſerved by *Rivinus* in the Membrane of the Tympanum, that ſome particular Smoakers, by ſtopping their Noſe cloſe, and ſhutting their Mouth, diſcharge the Fumes of their Tobacco by the Ear. This in-

How ſome Smoakers force the Fumes of their Tobacco thro' their Ears.

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* Obſerv. Phyſiq. Tom. II. p. 200.

† A great Anatomiſt, from whom this Canal derived its Name.

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ward Air, introduced by *Eustachius*'s Tube, supports the Membrane of the Tympanum ; and is what, being agitated by the external Air, communicates its Vibrations to the immediate Organ of hearing.

This immediate Organ, is contained in two other Apartments, each of them furnished with an Entry to the Drum, or first Cavity. This Cavity is, as it were, the Antichamber to those Apartments, which have besides between them another Entry of Communication. These Entries are likewise provided with Membranes. Nothing is so adapted to the putting all the Air in Motion, that is contained in these Sinus's, as the Membranes extended at the Entrance into them. The Drum and Kettle-Drum are Instances of this.

One of these Apartments is termed the *Labyrinth*, the other the *Cochlea*, or *Snail.*

The Labyrinth consists of a Vestibulum, from whence issue three semi-circular Canals, which form a little more than a half Circle, and then return to the same Vestibulum. The three Canals are particularly stiled the Labyrinth. I conceive that the Air, being pushed along the Vestibulum, and the Orifices of these Canals, the Vibrations of it that have insinuated themselves into each of those Orifices, must of course meet one another in the middle of each Canal, and there produce a Collision intirely accommodated to the exciting a Trembling, or Vibration in

in thoſe Canals, and the nervous Membrane that lines them: From this Impreſſion reſults the Senſation of Hearing.

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As this Labyrinth is ſimple and uniform, I conclude it is the general Organ of hearing, that is to ſay, the Organ that is agitated indifferently by all Sorts of Sounds or Noiſes; or, if you will, it is the general Organ of Noiſe. But the Cochlea ſeems to me to have a Conſtruction and Uſe more refined. Its Figure reſembles in Reality the Shell of a Snail. Its Inſide is compoſed of two Windings, or of two Sorts of Spiral Canals, and [ſeparated from one another by a thin and nervous Membrane, ſupported by the jutting out of bony Laminæ.

The particular Organ of Harmony.

The Artifice of this Conſtruction is of the moſt perfect Mechaniſm. The eſſential Property of an Organ of Senſation, is to be proportioned to its Object, and, in reſpect of the Organ of hearing, to be capable of being in Uniſon with the different Vibrations of the Air. Theſe Vibrations infinitely differ, and have a Progreſſion ſuſceptible of Degrees infinitely ſmall. It is neceſſary therefore that the Organ, formed to be in Uniſon with all theſe Vibrations, and to receive their Impreſſion diſtinctly, ſhould conſiſt of Parts whoſe Elaſticity is correſpondent with this ſame Progreſſion, this ſame inſenſible and infinitely ſmall Gradation: Now the Spiral is in Mechanics the ſole Machine productive of this inſenſible Gradation.

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It is evident, that the spiral Lamina of the Cochlea is intirely formed to be set a trembling by the Impulse of the interiour Air that surrounds it. It is manifest likewise, that the Lamina making, at the Basis of the Spiral, a greater Compass, has of course longer Vibrations, and that it has very short ones on its Top for a contrary Reason. Ply a Piece of Wire in the Cochlea, and you will find to what a Degree the great Windings will be put into Motion, and how stiff, on the contrary, will remain the small ones on the Top, or in the Center. Now from the Beginning of the Basis of the Spiral, where the Lamina is most supple, to the Extremity of its Summit, where subsists its last Degree of Rigidity, there is an insensible or infinitely small Gradation of Elasticity: insomuch that whatever Division is conceivable in the Tones, there is no one Sound at all that does not meet, in the Points of this Spiral, its Unison, or corresponding Vibration; So that there is no Tone unable to imprint distinctly its Vibration on this Spiral, and in this consists the grand Artifice of the Cochlea. It is for this Reason I look upon the Cochlea as the Sanctuary of the Hearing, as the particular Organ of Harmony, and of the most distinct and most delicate Sensations in this kind.

How Birds are Musicians.

Birds, you will object, have no Cochlea, and are nevertheless the most musical of the whole Creation. Birds have an exquisite Hearing, tho'

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not furniſhed with this Contingency, becauſe their Heads are almoſt intirely ſonorous like a Bell: which is owing to their not being involved in complicated Muſcles as are the Heads of all other Animals. Hence muſt they neceſſarily be agitated by the Sounds which preſent themſelves. Their Labyrinth being very ſonorous, is ſufficient for this End. The moſt ſimple Grott will echoe back a muſical Air: but if to this excellent Diſpoſition of hearing in Birds, Nature had added the Cochlea, they would have been much more ſenſible of harmonious Modulations. They would have had a Paſſion for Harmony, as almoſt all Animals have for gormandizing: which is not the Caſe. For one ought to recollect, that the muſical Quality peculiar to Birds, proceeds leſs from the Delicacy and Taſte of their Ear, than from the Diſpoſition of their Throat. They, furthermore, in this particular reſemble Muſicians, who give Pleaſure to others, without partaking of any themſelves. We hear a Dog howl, we ſee him weep, as it were, at a Tune played upon the Flute; when, on the contrary, this Animal is all alive in the Field, at the Sound of a French-Horn. The Horſe takes Fire at the Sound of a Trumpet, in ſpite of the thick muſcular Texture his auditory Organ is encompaſſed with. Without the Cochlea theſe Animals are provided with, one would by no means diſcover in them this Senſibility for Harmony. We ſhould

rather

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Stupidity of Fish.

rather find them, in this Respect, as stupid as Fish, which are destitute of the Cochlea, as well as Birds; but without the Advantages which Birds have of a Head sufficiently disengaged, sufficiently sonorous, to supply this Defect.

The Power of Musick.

Man unites all these mechanical Perfections, and moreover adds to them those delicate and refined Sentiments, which distinguish him from other Animals. It is this above all things on which depends his great Sensibility for Harmony. For that is good Musick, which expresses Sentiments, or excites them. It was in this kind of Musick the Antients excelled. Witness the following Instance in one of *Alexander*'s Musicians *:

Hear how Timotheus' *varied Lays surprise,*
And bid alternate Passions fall and rise!
While, at each Change, the Son of Libyan Jove,
Now burns with Glory, and then melts with Love.
Now his fierce Eyes with sparkling Fury glow,
Now Sighs steal out, and Tears begin to flow.
Persians *and* Greeks *like Turns of Nature found,*
And the World's Victor stood subdued by Sound!
The Pow'r of Music all our Hearts allow; &c.

This, which *Timotheus* produced in the Heart of *Alexander*, was no surprizing Phœnomenon among the Antients. It was the ordinary Effect of their kind of Musick †. Nor did they at all

* *Pope*, in his Essay on Criticism.
† See Monf. *Rollin*, Tom. II. Page 215.

all confine it to mere Diverſion, but employed it in the moſt ſerious public Affairs, and made it a Part of their Politics. It was not only introduced in their theatrical Declamations, but uſed alſo in their Harangues, to a Degree of Proſtitution. And it was partly by the Power of Muſick, that they tranſported the Hearts of the People, or the Soldiers, either with the Love of Peace, or Eagerneſs for War.

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Our famous *Lulli* ſeemed to have it in his View to revive this pathetic Muſick, theſe Sounds that penetrate to the Heart. And perhaps the *French* Maſters might accompliſh what that extraordinary Man only began, did they not run ſo much after *Italian* Caſcades, Muſic that rather ſurprizes, than touches the Paſſions.

What I here advance concerning the modern Taſte, is, notwithſtanding, no general Rule. We have ſtill in *Europe* Muſicians and Players on Inſtruments, that are ſtudious of good Muſic, and excel in it. It is but a very little while ſince there was at *Venice* an Artiſt, who, by playing on his Lute, inſpired his Audience with what Paſſion he pleaſed. The Doge had a Mind to have a Specimen of his Powers. The dextrous Muſician determined his Soul ſucceſſively from Melancholy to Joy, and from Joy to Melancholy, with ſo much Art and Energy, that the Doge, remaining no longer Maſter of his

The Hearing. his own Affections, ordered him to give over his Inchantments *.

Musick conducive to Health. This Power, which Musick has of moving the Soul, and by her Means the whole Machine, renders it very conducive to the Recovery of Health. And this Effect of it would be easily conceived, were we to reflect what Connexion there is between these two Parts of the human System. The Generality of Disorders consist in an Alteration of the animal Fluid, and its being affected by perverse Modifications. This Fluid is the Soul of Sensations and Passions; and it is owing to the Organs that it receives the Impressions of Objects, and takes the greatest Part of its Characters and Modifications. The Senses then are Organs very well adapted for changing the Character of this Fluid, and consequently of exciting in the whole Machine, which it animates, happy Revolutions. Now of all the Senses the Hearing is that which gives Man a Preheminence above all other Animals with Respect to Harmony: There is no Sense which causes in him such Emotions as this.

It is therefore no matter of Astonishment, that an exquisite Musician, seized with a continued Fever and Delirium, should be cured by good Musick †; nor that a Dancing-Master, attacked by a violent Fever, Lethargy, and Madness has recovered his Senses and Health by the same Means.

Every

* L' Existence de Dieu demontrée, pag. 171.
† Histoir. Acad. 1717.

The Hearing.

Every Body knows the Story of the Cure of *Saul*, by the Harp of *David*, and few Perſons are unacquainted with the Hiſtory of the *Tarantula*. The Sting of this Sort of Spider is not more painful than that of a great Ant, or of a Bee; but ſtill it is attended with very dangerous Symptoms, ſuch as Melancholy, Suffocation, Lethargy, Delirium, and even Death. Muſick is the only Remedy for this terrible Evil. The Method is to ſend for a ſkilful Muſician, who plays different Tunes upon different Inſtruments; for all Sorts will not anſwer the Purpoſe. The Inſtruments that ſucceed beſt are the Bagpipe, the Tambourin, Guitar, Lute, and Violin. The favourite Tunes are thoſe that are gay and lively.

Cure for the Bite of a Tarantula.

When the Muſician has pitched upon the ſalutary Inſtrument, and hit upon the Tune, he perceives the lethargic Patient to move, agreeably to the Time and Cadence of it, firſt a Hand, then an Arm, and ſucceſſively his whole Body. After which he betakes himſelf to dancing with an aſtoniſhing Activity, and that ſometimes for ſix intire Hours together. When they ſee him tired, they put him in a warm Bed, and when they think he has been ſufficiently repoſed, the Muſician attacks him with a new Saraband. This Exerciſe is continued, until they find the Patient tired, and that he begins to appear ſenſible.

These

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These Signs of Cure shew themselves generally at the Expiration of seven or eight Days. Then the Patient fancies himself to have come out of a profound Sleep, without any Idea either of his Illness, or the Jiggs he had been performing. Sometimes his Disorder leaves behind it a deep Melancholy, and sometimes likewise the Fit returns annually; in which Case there is a Necessity of recurring afresh to Musick.

Why the Bones of the Ear do not grow.

It is observable, as to the Organ of hearing, that the Labyrinth and the Cochlea do not at all increase in Size any more than the little Bones. They are as large in Infants as in Adults, altho' the external Bones of the Ear acquire a considerable Growth and Hardness. The Reason is, because the exteriour Bones are invested with a Periosteum well supplied with Nourishment, while the inner are divested of this Nourishment; and besides, the Bones are there of a Solidity that would even render it impracticable to receive any Nutriment, were it conveyed to them. One of those Authors who make it their Study to fish out Miracles on all Occasions, assigns no other Reason for this Phœnomenon, than the Will of the Creator; who, contrary to the ordinary Laws of Nature, has established the Bones of the Ear in a State of Non-accretion; that, as there was no Difference in regard of the Organ in Infants and Adults, there should be no Diversity in the Impressions that Sound should make either on these,

The Hearing.

theſe, or thoſe. He aſſures us, were the Hearing to increaſe, like the Growth of other Organs, Children as they advanced would receive this Impreſſion of Sounds in a different manner, and conſequently at a certain Age would no longer know the Voice of their Parents. This Author meant, that they might find an Alteration in their Parents Voice; but could never imagine they ſhould not know it to be the Voice of their Parents, as in that Caſe thoſe Children muſt have been blind. So that this Decree of the Almighty would then have been ſolely made for blind Children. But with what Foundation can we ſuppoſe that the Accretion of the Bones of the Ear ſhould make an Alteration in the Senſation of Hearing? The Organs of Sight, Taſte, Smell, do not theſe acquire Growth without diſconcerting thoſe Senſations? And tho' the Hearing be not ſuſceptible of making the like Advances, muſt one conclude from thence, that this Organ is the ſame in all Subjects? This is no ways probable. Every one hears therefore after his own Mode, as is evident, and feels and taſtes likewiſe proportionably to the particular Structure of his Organs.

Nothing in the mean while goes on at all the worſe. Wherefore let us revere the Deſigns of God, rather than dive too far into them; leſt, with the laudable Intention of publiſhing his wond'rous Works, we make him an Offering of

The Hearing.

the Folly of our own Imaginations. He has ſubjected the Univerſe to our Reſearches, to our Reaſonings; but not that we ſhould call his Decrees in Queſtion, and make him think and act agreeably to our weak Underſtandings. When we attempt this, methinks I hear one of *De la Fontaine*'s Inſects deſcanting on the ſublime Geometrical Operations of our *Deſcartes*, our *Newtons*, or on the profound Politics of our *Colberts*, and *Fleurys*.

Structure of the Ear in order to receive all Impreſſions of Sounds.

Of all the Organs of Senſation we have run over hitherto, we have ſeen that their Structure is contrived for the Penetration of their Object, and the Conveyance of its Impreſſion, and for its being, as it were, abſorbed in order to make a more perfect and compleat Impreſſion. This very Mechaniſm ſubſiſts alſo in the Organ of the Hearing. Every thing concurs to facilitate the Entrance, and to eſtabliſh the Retention of the Impreſſion of ſonorous Vibrations.

The exterior Tunnel collects theſe Vibrations. The next Tube, which conducts this agitated Air, diſcovers ſome oblique Sections at the bottom Parts of it made by the Membrane of the Tympanum. This Obliquity is the Cauſe why, on the rebounding of the exterior Air from under the Membrane of the Tympanum, it immediately ruſhes againſt the oppoſite Side of the Tube; from whence it is again reflected under the ſame Membrane to which it communicates all its Vibrations.

Were

The Hearing.

Were this Tube ſtrait, and perpendicular to the Membrane of the Tympanum, the exterior Air would be reflected from under this Membrane out of the Tube of the Ear, and conſequently would have a much leſs Effect.

In like manner the inner Air is ſhut up in the Sinus's by Membranes. The Vibrations it receives from without, enter on one Side the Orifices of the Labyrinth, and on the other thoſe of the Cochlea. The Vibrations that inſinuate themſelves into the Orifices of the Labyrinth, tend to make a reciprocal Colliſion amidſt the ſemicircular Canals; by which Action all their Effect is in a manner abſorbed in theſe Canals. Not that I imagine their Impreſſion is confined to the Point where this Colliſion is made, as the Rays of Light cauſe an Impreſſion where they are united; becauſe the Mechaniſm of theſe two Senſations is abſolutely different. Here it is a painted Image, there Vibrations, a Trembling, that communicates itſelf to the whole Organ by the very Colliſion that is made in ſeveral Points.

The Orifices of the Cochlea are twofold. One of them communicates with the Labyrinth or its Veſtibulum, and is the Entrance of the internal winding; the other opens itſelf directly in the Drum, or firſt Sinus, and is the Entrance of the external Winding. The Vibrations conſequent to theſe Openings are propagated the whole Length of the Spiral. But being arrived

The Hearing. at the Top, at the Extremity of the Cochlea, they undergo a Collision both against this impervious Extremity, and amongst themselves, and thereby give a Shock to all this Organ, particularly to the spiral Lamina, that Portion of it especially which is in Unison with the Vibration. So that all the Parts of the sonorous Vibrations are extinguished in the Organ of Hearing, in such a manner as to leave behind them all their Impression.

The inner Air of the Drum is supplied by *Eustachius*'s Tube; but the inward Air of the other Cavities is conveyed to them either by the Porosity of the Membranes that cut off their Communication with the Drum, or by the Fluids that circulate in the Periosteum of the Cavities.

We hear best with the Mouth open.

It is remarkable that we hear best with the Mouth open. The Reason of it is, because not only the Vibrations of the Air are communicated by the Mouth and *Eustachius*'s Tube to the Inside of the Ear, but moreover, because the Joint of the Jaw-Bone, placed against the Tube of the Ear, retires from it on opening the Mouth, and by that Means leaves this Passage more at Liberty.

An Instrument for relieving Hardness of Hearing.

The Structure I have been observing in the Ear, leads me to the Invention of an Instrument formed for supplying that Sort of Defect called *Hardness of Hearing*. My Machine consists of two Parts. The first is a Horn Shell that

that retains a good deal of Air, and is exactly fitted to the Tube of the Ear; the other Part is a Tunnel inserted at the Center of the Shell. The Hearing.

This Tunnel receives a good deal of exterior Air, put in Motion by those that are speaking. The Vibrations rush in Crowds, as it were, into the Shell, and communicate themselves to a vast Space of Air which it contains; and, being there retained and reflected by the vaulted Parts that surround the Tunnel, are obliged to unite themselves universally towards the Inside of the Ear, where they make a very strong and powerful Impression. The Figure of the Instrument exhibited in Plate IV. Fig. 4. points out the Nature of it more effectually than could be done by the most elaborate Description.

The nervous Organ, which immediately receives the Impression of Sound, is an extremely fine Expansion of the seventh Pair of Nerves, that line all the Inside of the Organ of Hearing. This Nerve has two Parts, one soft, that is expanded in the Cochlea and Labyrinth, and one hard, which distributes some interwoven Filaments to the Tympanum, or Drum, that pass behind the Membrane of the Tympanum, and make what is called the Cord of the Drum. But the greatest Portion of this Nerve is distributed in the Parts of the Face. The immediate Organ of Hearing.

The Hearing is one of the most valuable Senses, and the Loss of it may be ranked in the Number of the greatest Misfortunes. Tho' the

The Hearing. Taste be only absolutely necessary for Life, (for there is but little Difference between the Taste and Appetite;) yet Life, deprived of Sensations so useful as Hearing, is a kind of premature Death.

Utility of Hearing compared with that of the Sight.

I must nevertheless agree with those who look upon Deafness, that is not from one's Birth, as an Accident less grievous than Blindness. There are in the World more Objects of the Sight, than of the Hearing. And besides, Understanding is conveyed by the Eyes, not only by means of Writing, Books, *&c.* but also by Attitudes, Signs, and Motions of the Lips, Eyes, and Visage of those one beholds: witness the Pantomime Pieces so much in Fashion upon the *English* Theatre, and even in some Degree at this Time in *France*. It is certain, that the Sight is a Supplement to the Hearing, much more eminently than Hearing is to the Sight. The World abounds with deaf People whom we make to understand what we please. In the Year 1700 there was a Merchant's Wife at *Amiens*, who comprehended all that was said to her, by solely attending to the Motion of the Lips of whoever spoke to her. She joined in this manner in the most uninterrupted Conversations; which did not produce half the Fatigue that the ordinary ones by Speech are apt to create: For one might be dispensed with in regard of the Articulation of Sounds, it being sufficient to move the Lips as one does in speak-

Deaf that understand by the Motion of the Lips.

ing.

ing. Thus ſhe underſtood very diſtinctly, and would immediately tell you of it, in caſe you ſpoke a ſtrange Language to her *. There is recounted another Inſtance ſomewhat like this †.

The Hearing.

A Perſon born deaf is unavoidably dumb. For in order to ſpeak, it is neceſſary to learn a Language; and, to learn a Language, it is requiſite to hear. It is very perceptible that this Claſs of deaf People are for the moſt Part deprived of the Advantages and Conſolations we have remarked in the ordinary deaf. A Man deaf from his Nativity is, in my Opinion, a great deal more unhappy than one born blind. To form a right Judgment of his exceſſive Miſery, we need only reflect how valuable to Mankind are the Lights of Education, of which this Species of deaf Perſons is almoſt totally deprived. We have remarked, that there are more Things in the World that are the Objects of the Sight, than of the Hearing: but, in point of Knowledge, there are very few Truths that preſent themſelves to the View, being almoſt univerſally the Objects of our Hearing. We have, indeed, arrived at the Dexterity of teaching a Perſon deaf and dumb to read and write. By pointing, for Example, to a Candle, and writing down that Word, we ſhew that this is the Mark peculiar to that Thing; which he will

Deaf and dumb taught to read and write.

* Obſerv. de Phyſiq. Tom. II. p. 209.
† Ib. Tom. III. p. 279.

The Hearing. will recollect whenever you display to him that Character. One may teach him likewise the Names of his Friends, or rather the Figures that distinguish them. But who is not sensible how limited this Art of Signs is without the Help and Concurrence of Sounds? You make a deaf and dumb Man acquainted with a great Number of Substances, or Names of Things; but what Method will you take to apprize him of all the Appellations assigned to these Things? How will you make him comprehend the Verbs, their Moods, and Tenses? The Acquisitions, in Point of Knowledge, of this Class of Mortals, are confined to Matters intirely visible, and consequently are extremely limited, what Pains soever one takes to instruct them, and in spite of their natural Sagacity in guessing at the least Sign. We may judge of this Affair from the Account recorded in the History of the Academy of Sciences, of one deaf from his Nativity.

A young Man of about five and twenty Years of Age, born deaf and dumb, began all on a sudden to speak, to the great Astonishment of the whole Town of *Chartres*, where this singular Event happened. He gave out, that four or five Months before, he had heard the Sound of Bells, and was exceedingly surprized at this new Sensation. After this a kind of Water gushed from his left Ear, and he heard perfectly well with both. He continued in this State

The Hearing.

State three or four Months without uttering a Syllable, accuſtoming himſelf to repeat in a quite low Voice the Words he heard, and confirming himſelf in the Pronunciation and Ideas appropriated to thoſe Words. At length he determined on breaking Silence; and accordingly began to ſpeak, tho' his Accents were yet but imperfect. Some intelligent Divines ſoon got about him, and put Queſtions to him concerning his paſt State, which turned principally on God, on the Soul, on the moral Goodneſs or Evil of Actions. He did not ſeem to have carried his Thoughts thus far, tho' born of Catholic Parents, accuſtomed to attend at Maſs, and taught to make the Sign of the Croſs, and to kneel in a praying Poſture, which he had never accompanied with any one ſingle Intention: ſo true it is, that the greateſt Source of human Ideas ſprings from their reciprocal Commerce. I have given this Relation in the very Words of the Academy.

Of the SIGHT.

AMONG the Senſes there is no one ſo uſeful as the Sight; nor is it uſeful only, but likewiſe univerſally confeſſed to ſurpaſs them all in Point of Beauty and wonderful Effects. The Province of celebrating its Charms, I leave to the Poets. Its ſurpriſing Properties alone belong to me as a Naturaliſt; and, indeed, what Naturaliſt could avoid being inchanted by them? The Mechaniſm of Viſion has ſomething in it miraculous. Its Organ is a Prodigy of Dioptrics *, which the moſt conſummate Art muſt fall vaſtly ſhort of imitating. Light, which is its Object, participates of a Sort of middle Nature between Matter and Spirit †. It is at leaſt the pureſt Subſtance the Soul receives the Impreſſion of by means of the Senſes; and conſequently the Sight is, if I may ſo expreſs myſelf, the moſt ſpiritual of them all.

Mechaniſm of Viſion a Miracle of Nature.

Even the common Herd of Mankind look upon the Organ of Sight as the Mirror of the Soul. It is in the Eye, where ordinarily every one's Characteriſtic is legible, and predominant Paſſion

Sight the Mirror of the Soul.

* Dioptrics are a Part of Optics, which treats of the Paſſage of Light acroſs tranſparent Bodies.

† Mémoire de Mde. *Du Chatelet*, ſur la Nature du Feu, pour le Prix de 1738, p. 97.

The Basis of the Brain with its Appurtenances as large as Life —

Explanation of the Plate

A Fore Lobes of the Brain
B Middle Lobes
C Posterior Lobes

Δ a Portion of ye Pia Mater
1 Olfactory Nerve 1st pair
2 the Optic Nerve 2d pair
3d. pair or Motor: Oculorum
4th. pair
5th. pair. 6th. pair
7th pair or Auditive
portio Mollis thick
portio dura thin
8th pair, or par Vagum, or
middle Sympathetick
9th pair, or Lingual
10th pair to the Neck
11.12.13. the Cervical pairs
g Intercostal Nerve
e.f. their Origins which join
upon ye Carotide in the
Cavernous sinus
---- places where the Nerves
& Vessels perforate the
Dura Mater.
* the Anastomosis
of ye Lingual Branch
of ye Maxilary inferior
with ye Portio Dura+
a little before its exit
from the Ear
‡ a Ganglion of ye
intercostal, situated
on ye internal Carotid
X Productions of the
Dura Mater
which joins

s Ganglion of the
8th pair.

D. the little Brain, or Cerebellum
E. Medulla oblongata
F. Medulla Spinalis

a. the Strait Muscles of the Eye
b. The great oblique & pully
through which passes its Tendon
c. Lesser oblique
d. Optic Ganglion its Fibres
going to ye Eye, its Origin
from a Branch of ye Opthalmick
& from one of ye 3d pair, 3 —
Glandulous Bodies.
h. Nasal Branch from the
Opthalmick.
i. Lackrymal Branch
k. Branch of ye upper Lid
l.m. Anastomosis between the
Carotid & Vertebral
n. the Funnel
o. Mamillary Tubercles
p.q. Corpora Olivaria
et Piramidalia
r. Gulph of the
Jugulars

Paſſion painted; inaſmuch as this Organ, intirely nervous, and very nearly bordering on the Brain, abounds with Spirits, which muſt neceſſarily expreſs the reſpective Diſpoſitions.

The SIGHT.

Of LIGHT.

LIGHT, the Object of Viſion, is an extremely ſubtile Matter. This is an inconteſtable Point, which is ſufficient for our Purpoſe. It is not very material how its Parts are faſhioned: its prodigious Subtility is demonſtrated by the ſurprizing Facility with which it penetrates a Diamond, a Body of the greateſt Solidity and Gravity, and the leaſt porous of any Subſtance in Nature.

Light a very ſubtile Matter.

What we term Rays of Light, are the ſmall Filaments of which Light is compoſed, and alſo the elementary Particles, or the Corpuſcles that conſtitute thoſe Filaments, and which form the Matter of Light.

Rays of Light.

This luminous Matter is expanded all over the Univerſe, and all other Species of Matter are impregnated with it, ſomewhat like the Earth's being moiſtened with Water. The Sun is a Lake, a Sort of Ocean, where this Matter is amaſſed in greater Quantity, that is to ſay, with leſs of Mixture. Perhaps even this Light of ours is of a more ſubtile Nature, and ſofter than that of this Lake, according to the general Law eſtabliſhed in the Formation of

Light univerſally expanded.

The Sight.

the Univerſe, that the heavieſt Bodies ſhould ever occupy the Center of a Vortex. The Difference then that ſubſiſts between Light and Fire is only this; that in Fire the Parts of this ſubtile Matter are more maſſy and more agitated.

Luminous Matter not ſo maſſy as that of Fire.

That the Matter of Fire is more maſſy than that of Light, is evinced by Experience. In the middle of the torrid Zone, on the Top of the *Cordelieres*, (Mountains elevated above the Clouds, Wind, and Miſts) where of Courſe Light, and the Sun that animates it, ought to be endued with great Force, Cold, notwithſtanding, is there as exceſſive as in the North Seas *, proving mortal to thoſe who are not guarded againſt its Intenſeneſs. But who would imagine there could be a Poſſibility of running a Riſque of dying by Cold on a Mountain in the torrid Zone? Now from whence proceeds this terrible Extreme, in the midſt of a Region formidable by reaſon of its Heat?

By the juſt-recited Law, ſubtile Matter is ſo much the leſs ſubtile, and of ſo much more ſenſible Efficacy in regard to us, as it is nearer the Center of the Vortices; and it becomes ſo much the more ſubtile, diſſolved, and inefficacious in Proportion to its Diſtance from this Center. That which penetrates the Earth, and our Atmoſphere, is governed by this Law. The

* Abridgment of the Philoſophical Tranſactions, Vol. V. p. 147. or Le Spectacle de la Nature, Tom. IV. p. 199.

The Summit of the *Cordelieres* being extremely elevated in the Atmosphere, the Action of the Sun in this Region only puts in Motion a very subtile Matter, that is but one Degree beyond pure Light. Now the Impression of such a Matter is reserved for the sole Delicacy of the Sense of seeing. But, in respect of our other Solids and Fluids, this Matter makes its Way freely, and penetrates them almost without at all affecting them, its Motion dying away irresistably, and without the least Agitation of the Parts. As it cannot then make any material Impression on them, a Cessation of Motion in our Fluids necessarily ensues, as the principal Part of their Motion is owing to the Fluids of the Universe which penetrate them; and, in short, a total Stagnation of the Blood and Juices, with the Death of the Animal, follows. It is to the same Cold of mountainous Regions, we must ascribe the Origin of Hail, that is to say, of congealed Water, which falls sometimes at *Midsummer*.

The SIGHT.

Why several have died of Cold on the Top of the *Cordelieres*, tho' in the Torrid Zone.

Hail falling sometimes in Summer accounted for.

In a less elevated Region, as on the ordinary Surface of the Earth, we meet with a Matter less subtile, more massy, and capable in a greater Degree of affecting our Fluids and Solids, of rarifying both the one and the other, and of producing those Motions and Agitations, called *Heat*. And these Effects would be still more considerable, were the Agitation of this Matter increased by the Action of the Sun.

Cause of Heat.

If

The SIGHT.

If we descend below the Surface of the Earth, and penetrate into the Bowels of it, even to those subterraneous Caverns where the Sun's auxiliary Action can have no Access, at least directly, we should notwithstanding by no means incur the Hazard we should be exposed to on the mountainous *Cordelieres*; as the Bulk and Solidity of the subtile Matter, and its inherent Motion, that receives an Augmentation the nearer it approaches to the Center, supply the Loss on the Part of the Sun. It is this fiery Matter diffused in the Entrails of the Earth, that constitutes the central Fire, so analogous to the Caustic Fluid established in the animal Œconomy. It is that which renders Places under Ground hot in Winter *, and the more so the deeper they descend, according to the Experience of Monsieur *Mariotte*. And as both Men and Beasts have been killed by the Cold, and found in a manner petrified, on the Top of the *Cordelieres*; so, on the contrary, several have died by Heat, and become in a manner dissolved in Caverns of the Earth of an extreme Depth.

Central Fire.

Matter of Light finer and softer than that of Fire.

The Rays transmitted to us from the Moon, is a farther Proof that the Matter of Light is a great deal more subtile, and much finer, and softer,

* Subterraneous Places are equally hot in Summer. From the Heat of Summer it is, that one finds them cold at this Season of the Year, as it is the Cold of Winter, that makes them feel hot. But in Reality, this Heat is the same at all Seasons, because the Central Fire is ever the same.

softer, than that of Fire, and very little capable of producing the Effects of that Element. Monsieur *De la Hire* the younger, during a fine full Moon, exposed to the Rays of this Planet the great Burning-Glass of the *Observatoire* at *Paris*; and applied to its Focus the Bulb of Monf. *Amontons*'s Thermometer, which is endued with the greatest Sensibility, if one may use the Expression, of any we have. The Mercury rose not at all, altho' by this Glass the Rays were collected into a Space three Hundred and six Times smaller than their natural State; when they ought consequently to increase the apparent Heat of the Moon by so many Degrees. The *Urania* of our Age *, so versed in these sublime Experiments, adds, that the Rays of the Moon thus united, are more dense and compact than those that issue from a Wax-Candle, tho' this Candle nevertheless burns with a lively Blaze, and these Rays of the Moon cannot so much as imprint the least Sign of Heat even on an Instrument susceptible of her lightest Impressions. Whence it is evident, that the Matter of Light is different from that of Fire and Heat, and a great deal grosser.

The SIGHT.

Experiment of Monf. *De La Hire.*

But how comes the Burning-Glass of the *Palais-Royal*, in assembling a great Quantity of Rays in a small Space, to produce the most terrible Fire imaginable; a Fire, that in an Instant puts in Fusion the most compact Substances, such as

Why the Burning-Glass of the Palais Royal melts Gold and precious Stones.

* Mde. Du Chatelet, loc. citat.

The SIGHT.

as Gold and precious Stones? The Reason is, because this great Quantity of Rays is intimately united to the Matter of the Fire that is in the Atmosphere; which being borne and animated by these Rays, is crowded jointly with them in the Focus of the Glass, and there works the prodigious Effects in regard of which Light is only the Soul, or first Mover.

Tho' this luminous Matter be universally diffused, it does not alwas manifest itself, at least to ordinary Eyes. It has a Motion, like all subtile Fluids; but this Motion is not of Energy sufficient to make an Impression on our Sight: or rather, the Motion it partakes of as a Fluid, is not that which it ought to be endued with, as an Object of Vision. The Air is therefore incessantly in Motion as a Fluid: but, in order to produce Sound, it is necessary it should be furnished with the supernumerary Motion of Vibration, or Undulation, it receives from sonorous Bodies. In like manner the Matter of Light, besides its Motion of Fluidity, necessarily requires Vibrations excited either by the Sun, or the Stars, Fire, or in short by some luminous Body, whatever it be. These Vibrations are always made in a direct Line.

Vibrations necessary to luminous Matter.

The Sun is generally acknowledged to be the most powerful Mover of this Matter. Consequently its Absence involves it in Darkness, not because the Force it acts with upon this Matter is absolutely confined to the Parts it pushes

puſhes in a ſtrait Line; the neighbouring Particles are likewiſe agitated, which is partly the Cauſe of Twilight. It is alſo the Reaſon why we ſee a Solar Ray that darts into a dark Room, tho' one be ſideway, and at a Diſtance from the Ray. But, in Proportion to the Diſtance of theſe Particles, this Communication of Motion becomes ſo feeble, that at laſt this Light is no longer capable of ſtriking the ordinary Organs. In the ſame Manner as when a Perſon is behind a thick and high Wall, he ſcarce hears any one that is talking on the other Side.

The SIGHT.

Cauſe of Twilight.

It muſt notwithſtanding be acknowledged, that one may better hear a Man ſpeaking on the other Side of a Wall, than be lighted by a Flambeau placed behind the ſame Wall. There are two Reaſons for this Difference.

Firſt, the Motion of Light is intercepted and extinguiſhed much more eaſily than that of Sound. A ſingle Piece of Paper is capable of veiling Light, and even of extinguiſhing it. But a Man between four Stone-walls can make his Voice be heard at a conſiderable Diſtance; becauſe Sound ſurmounts the greateſt Reſiſtances, puts in Motion the moſt ſolid Bodies, and of Courſe forces its Impreſſion beyond thoſe Bodies: If I hear the Voice of a Man from behind a Wall, the Sound of it is communicated to me partly thro' that very Wall; a Reſource that luminous Vibrations are totally deprived of.

Motion of Sound more powerful than that of Light.

Secondly,

The LIGHT.

Secondly, the sole Communication which Sound has here in common with Light, is above the Wall. Its Beams expanded in the Air above the Wall, light me, very feebly indeed, but still they afford me some Light: Direct Vibrations would, no doubt, light me compleatly. In like manner I should more distinctly hear the Sound of a Voice, if it came directly to my Ears. But it is sufficient for me to see a little of the Light, which passes above the Wall, to conclude, that there are in luminous Matter Vibrations, and collateral Undulations, resembling those in the Air subservient to the Production of Sound. These lateral Vibrations are in a lesser Degree, and the direct on the contrary more lively, which is an Effect of the Subtilty of this Matter so superior to that of Air. If you strike upon a Piece of Timber, every Part of it will shake almost equally. But if one beats the Water in a Lake, the Vibrations will not be so universal; in Air, they are still less; and in Light less still, than in all other Fluids: because the more subtile a Fluid is, the less connected are its Parts, and the more independent of one another; and consequently their direct Motions may be made with so much the less Communication between the collateral Parts, and of Course with so much the greater Velocity. It is for this Reason, that the Propagation of Light is by several Degrees quicker than that of Sound.

Vibrations in luminous Matter, and collateral Undulations.

Why Light is propagated with greater Velocity than Sound

When

LIGHT.

When I ſay that the Motion of Light in the Sun's Abſence, or the Abſence of any other luminous Body, is not of ſufficient Efficacy to make us ſenſible of any Properties it is endued with by agitating our Organs, I mean the ordinary Organs. For there are Eyes, in regard of which there is no Night, or at leaſt no Darkneſs, properly ſo called.

Why Owls ſee by Night.

The Owl ſees in the Night *, inaſmuch as the Ball of its Eye is ſuſceptible of an extreme Dilatation, by means of which its Eye collects a great Quantity of this feeble Light, which great Quantity is a Supplement for its Defect in Point of Force. Perhaps too this Animal is furniſhed with an Organ of Viſion ſome Degrees finer than ours. *Briggs* knew a Man, who was not a Jot behind the Owl, being able to read in the Dark. The Cat alſo is reckoned a Rival of the Owl in this Particular, as well as the Mole in its ſubterraneous Atchievements. It is pretended alſo, that Men in certain Fits of Drunkenneſs, and Acceſſions of a Fever, or when choleric, will read in the Dark.

And Cats.

The young Woman of *Parma*.

There was a young Woman at *Parma*, who could ſee as clearly at Midnight when all the Windows were ſhut, as if it had been Noonday. Mr. *Boyle*, in his Diſſertation touching final Cauſes, *&c.* makes mention of a Gentleman confined in a Dungeon abſolutely dark, who, having been there ſome Weeks without

Strange Story related by Mr. *Boyle*.

G ſeeing

* Obſervat. Phyſiq. Tom. II. p. 198.

The Sight. ſeeing any thing, imagined at laſt that he diſcerned a little Glimmering; which Glimmering increaſed daily, ſo that he could now ſee his Bed, and Objects of the like Bulk. At length he could ſee even the Rats that came for his Crums, and mark their Motions very diſtinctly.

It is certain that a Place muſt be exceedingly dark indeed, where a Perſon who has remained there any long Time cannot plainly diſcern Objects. This is obſervable every Day in a dark Chamber. The principal Reaſon aſſignable for our Inability of ſeeing in the dark, is the great Light our Eyes are accuſtomed to. This Organ is, as it were, worn out with it, in the ſame Senſe as we ſay Tiplers have loſt their Taſte. We have ſeen how the Boy brought up in a Foreſt, and accuſtomed to weak Odours, had his Smell in as much Perfection, or rather more exquiſitely, than Hounds. I imagine, that any one uſed to Darkneſs would likewiſe have a Delicacy and Sharpneſs of Sight ſufficient to produce a diſtinct Perception of Objects. It is therefore the Defect alone of our Organ, if we do not ſee at all Times. For we are inceſſantly ſurrounded with Light, and with Light that is more or leſs ever in motion. This Truth is farther proved by an Inſtance in the *Journal des Sçavans* of 1677, which here follows Word for Word. A Man having wounded his Eye with a Wire, which he broke in ſtringing his Lute, after making uſe for ſome Days of

Defect of the Organ, the Cauſe why we do not always ſee.

Strange Story in the *Journal des Sçavans.*

of cooling Remedies, that were prescribed him, in order to preserve his Eye from the Inflammation that threatened it, all on a sudden found he could see clearly enough, in the midst of Darkness, to discern every Object, and to read all Sorts of Characters. This Symptom continued for several Days, or, to speak more properly, several Nights: during which Interval he saw nothing but with his sick Eye, that could not in the mean while bear even the Light of a Candle, much less that of the Sun in the Day-time, so that he was then obliged to keep it shut.

The Sight.

This Man, as is plain, had his Day-Eye, and his Night-Eye, and the Reason of it is evident. The Inflammation of the diseased Eye had rendered it sufficiently sensible of being as much affected by the feeble Images of nocturnal Light, as the sound Eye was by those of the Day. So that this latter Species of Image must rather wound this disordered Organ, than enlighten it.

Propagation of Light.

Light being always existent, and diffused thro' the whole Universe, as we have been just observing, the Shocks communicated to it by the Sun, or every other luminous Body, put it into successive Motion in the same manner, as the Vibrations of a sonorous Body agitate the Air to a wide Degree of Circumference. We have specified the Time these Vibrations or Sound takes up in passing thro' a given Space. Light, all subtile as it is, employs also a certain Time

The Sight. to communicate itſelf; but this Time is proportioned to its Subtilty. For Example, it is ſeven or eight Minutes in arriving to us from the Sun, that is to ſay, in making thirty Million of Leagues. It is about four Millions of Leagues in a Minute, and almoſt ſeven Hundred Thouſand Leagues in a Second. What a prodigious Rapidity of Communication, compared to the three Hundred forty-ſix Yards, which Sound is propagated thro' in a Second, and to the four Leagues and a half, which it makes in a Minute! Light is tranſmitted almoſt a Million of Leagues for every ſingle League that Sound is traverſing. It is therefore a thouſand times more ſubtile and more rarified than Air that produces Sound.

By admitting this great Superiority of Light, one conceives the Poſſibility of this rapid Propagation. But the Opinion of thoſe who imagine that Light is tranſmitted to us by the Emanation of the Sun itſelf, that this Matter actually travels the Space we have been mentioning, that it parts from the Sun, and reaches us in ſeven Minutes; this Opinion, I ſay, ſeems beyond all Probability. A Cannon Bullet, with its utmoſt Swiftneſs, would take up five and twenty Years in making the like Way. Now ſuch Velocities are as impoſſible, as the Revolution of all the Firmament in a Day round the Earth.

Error of ſome Philoſophers.

The

Plate. III.

Fig 1

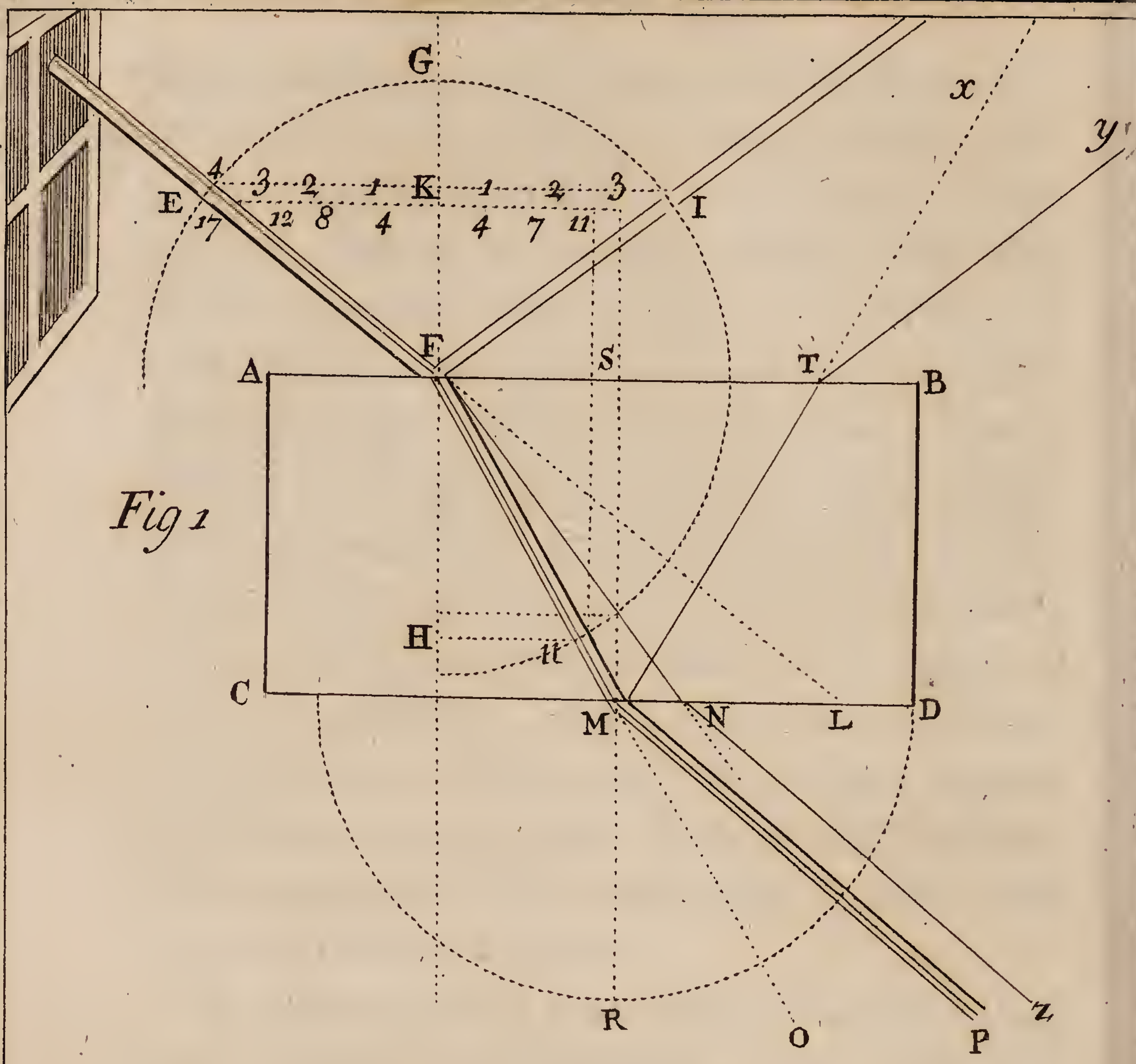


Fig. 2.

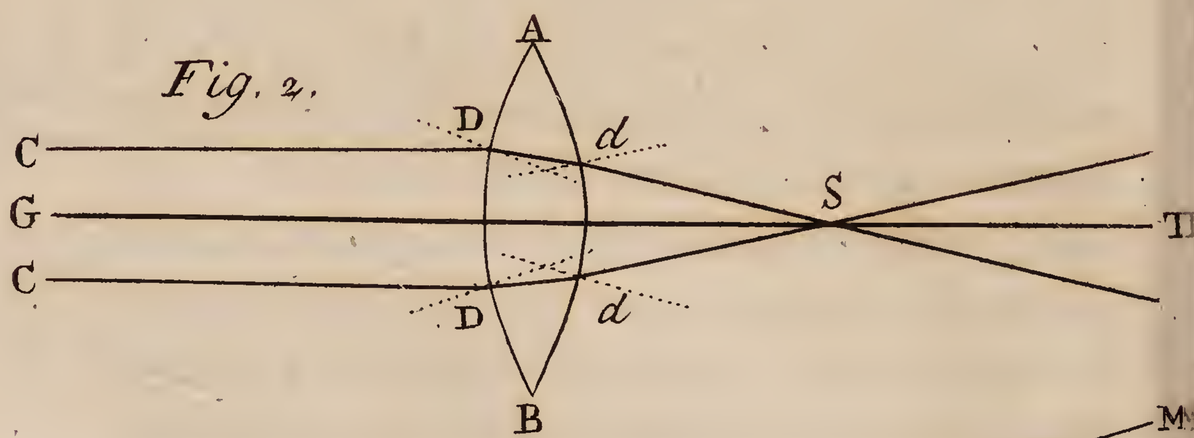
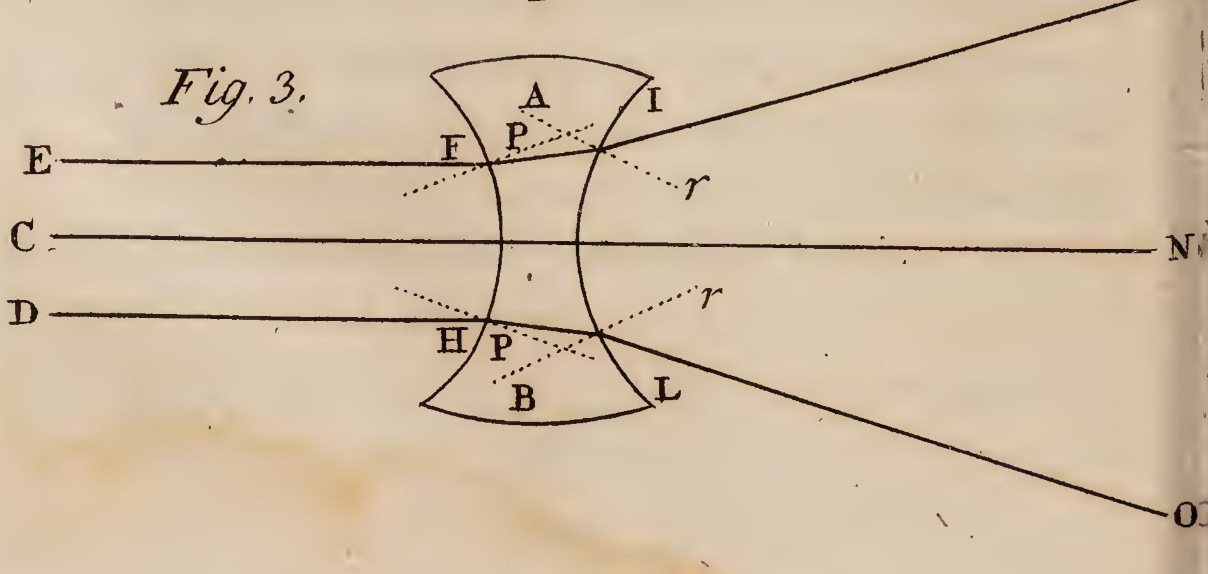


Fig. 3.



The Reflexion *and* Refraction *of* LIGHT.

THE Propagation of Light, or, if you please, its Motion, is ever in a direct Line. The Way Light is propagated.

This Motion of Light, in a direct Line, changes its Direction when it meets with a smooth Surface, for Instance, that of a Looking-Glaſs, or when it paſſes obliquely from one Medium to another, as from Air to Water.

The Change of Direction of the Rays of Light, by falling upon a ſmooth Surface, is called *Reflexion* of Light; becauſe the Light reflects, or rebounds, from this Surface, as a Ball does from a boarded Floor. Experience has taught us, that Light is reflected from theſe ſmooth Surfaces, with the ſame Force, and the ſame Inclination, with which it fell upon them: or, in other Words, that the Angle of Incidence EFK of the Ray EF, Fig. 1, Plate III. and its Angle of Reflexion KFI are equal. Reflexion of Light.

The Change of Direction incident to Light, that paſſes from one Medium to another, is but a turning of the firſt ſtrait Line, which turning of Light is termed *Refraction*; becauſe in Effect the Ray thus determined from its firſt Direction ſeems to be *broken*. Refraction.

Tho' it be not Light which really falls upon theſe Surfaces, or actually paſſes in theſe Me-

LIGHT. diums, but only the Vibration, that is communicated to the luminous Matter which is already upon these Surfaces, and in these Mediums ; we make no Scruple nevertheless of saying, that Light falls upon a Surface, that it passes in a Medium, inasmuch as these Expressions are more conformable to the common Way of conceiving their Effects. It is sufficient to acquaint the Reader, that we mean no more by these *Falls*, or this *passing* Quality of Light, than the Propagation of luminous Vibrations.

When the Medium, wherein Light enters obliquely, is of greater Density than that in which it was, for Example, when it passes from Air into Water, or from Water into Glass, it is refracted in approaching the Perpendicular drawn in this new Medium, to the Point of its Surface where the Light falls. The Ray EF, that falls in Air upon the Cube of Glass or of Water ABCD, would pierce it according to the Direction FL, if this Cube contained only Air ; but consisting of Glass or Water, the Ray is refracted in approaching the Perpendicular FH according to the Direction FM, if the Cube is of Glass, and according to the Line FN, if the Cube is of Water : because Glass being of a greater Density than Water, refracts the Ray the more, or determines it the more to the Perpendicular FH.

But in case Light passes obliquely in a Medium of greater to one of less Density, it is refracted,

fracted, or turned, on withdrawing itſelf contrarily to the Perpendicular of the Medium which it pierces. For Inſtance, when the Ray FM, which has pierced the Cube of Glaſs ABCD, paſſes afreſh in the Air that is below this Cube, inſtead of keeping the ſtrait Line FMO, it is refracted from M to P on its Direction from the Perpendicular MR of all the Space OP. LIGHT.

This is what is called the *Refraction* of Light. We are convinced by Experience, how much Light is turned from its direct Way in every Medium. For Example, in paſſing from Air into Water, it diverges a Fourth of its natural Diſtance from the Perpendicular; in Glaſs it diverges almoſt a third, or ſix ſeventeenths. When it quits theſe denſe Mediums to paſs in Air, it is as far diſtant from the Perpendicular, as it had approached it on its Entrance: that is to ſay, it is refracted a fourth Part on leaving Water, and about a Third when it retires from Glaſs. So that the Ray EF above the Cube, and the Ray MP below it, both in the Air, are parallel to one another.

The Geometricians expreſs themſelves more exactly; tho', perhaps, not with a Clearneſs neceſſary for the Generality of our Readers.

I will only ſpeak one Word in regard of thoſe to whom I ſhall explain theſe Matters, and of thoſe, who underſtand them already, that the Geometric Method of accounting for the Refractions of Light, is expreſſed in the

LIGHT. Plate; where they will find, that the Sine of Incidence EK is to the Sine of Refraction in Water K 3 or H 3, as 4 is to 3, and that this same Sine of Incidence EK, is, to the Sine of Refraction in Glass, K 11 or H 11, as 17 is to 11, and *vice versa* as to the Refractions of the Ray that passes from the Cube into Air.

If the Surface of the Medium into which Light enters is found convex, as is the Lens AB, Fig. 2; then supposing three Rays Parallel GCC, the middle Ray G, falling perpendicularly on the Medium of the Lens, will pierce it without being turned from its first Direction, and will describe from G to T but one strait Line. But the collateral Rays CC, falling upon the lateral and sloping Parts of the Lens, become oblique, in respect of the Perpendiculars of this Spot of the Surface, marked by the two pointed Lines DD: so that they are refracted on their approaching this Perpendicular DD.

These same Rays, on departing from the Lens into Air at the Points dd, pass obliquely from a denser Medium to a Medium of less Density. They must consequently then be broken, on their Determination from the Perpendiculars marked in the Plate. So that they would always be approaching the middle Ray, to which they would unite themselves at last in a single Point S; where they cross one another, and from whence they are separated afresh at T.

This

This Point of Re-union, is called the Focus of the Lens, and theſe Rays, thus conducted to the ſame Point, are termed *convergent* Rays ; but, when they ſeparate themſelves again as at T, they are ſtiled *divergent* Rays.

LIGHT. Focus of the Lens. Convergent Rays. Divergent Rays.

If, on the contrary, the Surface of the Medium, into which Light enters, be concave, either on one Side only, or on both, as in the Lens AB Fig. 3 ; then the middle Ray C will croſs the Lens in a direct Line CN : becauſe this Ray falls perpendicularly both on the concave Surface FH of the Lens, and the convex Surface IL of the Air. But the collateral Rays ED fall obliquely upon one and the other Surface ; whence they become ſubject to the Laws of Refraction.

They enter at the Points FH into this denſe Medium. Inſtead of keeping in a ſtrait Line, they muſt neceſſarily be diverged in approaching to their Perpendiculars p, p. They depart from the Lens, or paſs into Air of leſs Denſity to the Points IL. There, inſtead of purſuing again a ſtrait Line, they muſt keep wide of their Perpendicular rr, and go to M and O : conſequently, theſe Rays are twice diverged from the middle Ray, which renders the intire Ray *divergent*, in a contrary Direction to that which paſſes thro' the convex Lens.

We muſt obſerve, that in the one and the other Glaſs, tho' the Ray in entring makes its Approaches to the Perpendicular, and at its

Light. darting away is wide of it, it ever continues notwithstanding to approach the middle Ray, as in the convex Glass, or to keep wide of it, as in the concave. And the Reason is, because the Perpendicular of its Entrance, and the Perpendicular of its Exit, from the Glass, are under contrary Directions. So that the Ray in its Approaches to the former, and its keeping clear of the latter, is always curved in the same manner.

Sequel *of the* Motions *of* Light; *their* Causes.

New Properties of Light.

SUCH are the principal Properties of Light known before Sir *Isaac Newton*'s Time. In order to display those, which this great Man and other his learned Contemporaries have added to these, let us have Recourse to the Cube of Crystal, Fig. 1. Plate III.

Reflexion from under the Cube of Crystal.

The Ray EF falls upon the Cube of Crystal at the Point F. A Part of this Ray is reflected from under the Surface of this Cube from F to I; a Portion of it breaks even at M, as we have intimated; a Portion of this Ray at the Point M is reflected from under the Surface of Air from M to T, where it is broken from T to Y, instead of going directly to X. Another Portion, which it is impossible to delineate in a Plate, is scattered in the Glass. One Part of this is lost, extinguished in the Crystal; the other

other is illuminated, and darts away from every Point. Sir *Isaac* has observed, that this Light, scattered in a Cube of Crystal, is tossed like a Ball, as it were, between the Surfaces of the Cube, by Thousands of Vibrations, like those we have admitted for the Propagation of Light.

LIGHT. Vibrations of Light in the Cube of Crystal.

In fine, the same Gentleman has remarked, that if a Ray falls perpendicularly upon a Cube of Glass, as from K to F, its Motion increases at its Entrance, and is accelerated from F to H, far from being retarded by its Rencounter with the Glass, as was the Opinion of the Antients.

Acceleration of the Rays perpendicular to the Crystal.

The Followers of Sir *Isaac Newton*, in order to solve these Phœnomena, say that each Particle of Matter is endued with an attractive Quality; that this Quality, tho' immaterial, is notwithstanding attached to Matter, and that the more a Body consists of material Parts, the stronger is the Force of Attraction.

Causes according to the Followers of Sir *Isaac Newton*.

In this System Light is attracted by transparent Bodies in the same Manner as the Loadstone attracts Steel-Dust. So that when a Ray, as KF, falls perpendicularly on a Cube of Glass, which already attracts it, this Attraction of the Glass, joining itself to the first Motion of Light that is in the same Direction, so much the more augments the Motion of this Ray, which enters then the Glass with the greater Velocity.

But if a Ray falls obliquely on a Cube of Glass, as EF, then the Attraction of the Cube, which acts perpendicularly to its Surface, does not

The SIGHT.

not at all occur in the ſame Direction as the Ray, this tending to L, the Attraction exerting itſelf at H. So that the Ray being between theſe two Powers, is forced to take the middle Road FM.

Why the Velocity of the Ray is leſs in Water.

This Velocity of the Ray is leſs in Water, becauſe Water does not contain ſo much Matter as Cryſtal, and therefore has leſs of Attraction.

The ſame Effort of Attraction, which broke the Ray at its Entrance into the Cryſtal, breaks it ſtill more at its Exit; becauſe this Attraction exerts itſelf on all the Surfaces of the Cryſtal, to puſh the Ray towards the Surface it is neareſt to.

Cauſes of theſe Effects according to the *Carteſians.*

A *Carteſian*, to account for theſe Effects, has preciſely nothing elſe to do, than to ſubſtitute the Word Impulſion for that of Attraction, and to eſtabliſh it as a Principle, that this Property is produced by the Fluid which ſurrounds the Cube of Cryſtal. He will reap two Advantages over the *Newtonian* Philoſophy. The firſt is, that his Cauſe is univerſally known and truly mechanical; the ſecond, that it explains all the Phœnomena obſerved by Sir *Iſaac*, and thoſe even which are inexplicable by the Doctrine of Attraction. This we are going to ſee, in continuing to obſerve our Ray fallen in the Cube of Cryſtal, in Fig. 1.

Two Advantages over the *Newtonian* Syſtem.

One Part of the Ray FM is reflected from the Bottom M of the Cube of Cryſtal towards T in the ſame Manner, as a Part of the Ray

EF

EF which falls upon this Cube is reflected from F to J. LIGHT.

The *Newtonian* Philosophers, to explain these two Effects, are necessitated to assert, that these Reflexions result from a Vacuum, in Contradiction to two evident Propositions; to wit, that smooth Surfaces reflect Light, and that a Vacuum is incapable of Reflexion. Recourse of the *Newtonians.*

As a Proof that it is from a Vacuum these Rays are reflected, and that Attraction is the universal Mobile of Rays, they add, that in case we place Water under the Cube, the Reflexion MT is much less, because Water attracts Part of these Rays. If, on the contrary, the Air be pumped from this Cube, and there be produced a Vacuum, the Reflection becomes the more compleat. It is therefore the Vacuum that is under the Cube, and the Attraction of the Cube, which reflect and render more vivid this Portion of Ray. Now if an immaterial Cause reflects a Ray from the inferior Surface of the Crystal, why shall not a Reflexion from the Surface above be consequent to the same Cause? They subjoin to these Reasons the prodigious Inequalities of the smoothest Ice, which they do not look upon at all as endued with a Property of reflecting Light regularly enough for the Formation of Images.

Newtonian Attraction the Impulsion of the *Cartesians.*

The Reflexion from the lower Surface of the Crystal, on which the *Newtonian* Philosophers build their Foundation, is a Proof that Attrac-

tion,

LIGHT. tion, which is their general Cause, is nothing else but the very Impulsion of the *Cartesians*.

What Attraction is. Attraction is a Force by which one Body is made to approach another; and its Effect ought to extend itself to, and terminate in, the Center of the attracting Body. But the Ray MTY, reflected from the Cube, is impelled a good way beyond the Body where the Attraction is supposed to be. This Reflexion therefore is not at all produced by any attracting Virtue peculiar to this Body. For such a Property would carry the Ray to the Center of the Glass, and the Cube of Glass would absorb this Ray, as a Spunge sucks up Water which it seems to attract. Wherefore this Reflexion is caused by an Impulsion, that is exterior to this Body, and which surrounds its Surface.

In effect, since we see that a Ray, which falls upon a Glass or upon the Surface of Water, is reflected in Part, why may not the Ray that has pierced this Glass or this Water, and falls upon the Surface of Air, be also reflected from this Surface? If one pumps out the Air, the Reflection becomes the stronger. From whence I conclude, that there remains still under the Crystal, a Matter, which its Subtilty and Motion render more proper to repel Light; and that this Repulsion is not at all the Effect either of a Vacuum, or of Attraction.

The impelling Force of a surrounding Fluid, which under the Crystal is very capable of repelling

pelling Light towards the Cube of Glaſs, and beyond the Cube, will not loſe any of this Power on the upper Surface of the Cryſtal: and it is this impelling Power which we have already aſſigned as the Cauſe of Refraction, and of the Velocity of Light. LIGHT.

As to the Reflection of a Ray from the Surface of the Cryſtal, which the *Newtonian* Philoſophy attributes ſtill to a Vacuum; it is evident both to Reaſon and our Senſes, that it reſults from the very Matter of the Cryſtal, and not from a Vacuum. Light is reflected by the actual Matter of Bodies.

The Vacuum is a Space intirely formed for the Reception of Matter, and no Ways capable of reſiſting it, or of reflecting it. M. l'Abbe *des Fontaines* * and *Bannieres* † have ſolidly proved its Impotence in this Reſpect. But I do not know whether what a Gentleman of great Penetration, Monſieur *de Voltaire*, has delivered on this Head in the 140th Page of his Elements, is not ſtill a ſtronger Proof againſt the *Newtonian* Syſtem. " The inherent Attraction of Matter, ſays he, is not at all extended to the whole.—The Myſtery of Light reflected from amidſt Pores and from Surfaces, without touching thoſe Surfaces, has Depths that are unfathomable by the Laws of Attraction." Proved. *Voltaire's* Sentiment.

In

* Obſerv. ſur les Ecrits des Modernes, Tom. 15 and 18.
† Examen & Refutation des Elemens de la Philoſophie de *Newton*, &c.

LIGHT.

In effect, it would be here in vain for those Gentlemen who adhere to Sir *Isaac Newton*'s Principles, to call in Attraction to their Aid. This Force, whatever it be, acts perpendicularly to a Cube, and towards this Cube. It cannot therefore repel Light from thence; and, consequently, cannot produce this superior Reflection, which is in a contrary Direction to its Action. It is neither a Vacuum, nor Attraction, that produces the Reflexion of Rays. This Reflexion therefore proceeds from the actual Matter of the Glass.

Refutation of the reflecting Varnish substituted in lieu of the *Newtonian* Vacuum.

In the mean while some Naturalists, dazzled by that Philosopher's Experiments, and frighted at the same Time by his System of a reflecting Vacuum, have hammered out a third Opinion, a Sort of a Medium between the other two. They agree with the *Newtonian* Party, that Light is not reflected from under Bodies; but they pretend it is from under a Fluid, with which the Body is impregnated, and forms upon this Body a kind of Varnish *. To deliver my own Sentiments, this Bed of Varnish serves only to cover the Vacuum and the Mistake of Sir *Isaac Newton*; for it cannot stand the Test of a Counter-Examination, disappearing on producing the least Proof against it. Nor is the Reflexion of Light assignable to any other Cause, than either to the Pores of Sir *Isaac*, or the Matter of *Des Cartes*, and all real Naturalists.

Monsieur

* Monf. *De Mairan*, Journal des Sçavans, 1719.

Monsieur *Bannieres*, and some others, compose this Varnish with Light itself. According to them, this kind of Light takes up its Abode in the Pores of Bodies, is the Property of each Body, and forms for it a Sort of Atmosphere. It is red in red Bodies, blue in blue, *&c.* and a Body is not red for any other Reason than because it is full of this red Light; which on Account of the Analogy reflects only red Rays, and extinguishes others.

LIGHT. Opinion of Monsieur *Bannieres*, &c.

But, in my Opinion, this Analogy must precisely hinder red Light from reflecting red Rays. I should imagine, that these two Lights, being of the same Nature, would be rather united and attracted, as Oil is joined to Oil, and seems to attract it. So that these Philosophers would seem to me to have a better Foundation, did they make this Analogy subservient to a kind of Attraction that displays itself in Refraction, and not subservient to Reflexion. Because these Effects being opposite, their Causes of Course ought not to be the same.

Refuted.

Again, from whence comes it that a red Body is impregnated with red Light, rather than that of another Colour? The Reason is, they will answer, because the Configuration of its Pores, or its Texture, is more susceptible of receiving red Rays. But if this Body received red Rays, the Vibrations of the red Rays exterior to the Body, would penetrate it, sink the red Rays that already quietly fill the Pores, and

LIGHT. would chase them from these Pores by the same Vibration which they have in a greater Degree than those Rays. In short, a corporeal Texture, proper to absorb or let pass red Rays, will never be endued with a Faculty of stopping and reflecting them: Such a Body therefore will not appear to us red.

If the Texture of a Body does not stop, or reflect, the exterior Rays, it will neither be able to retain the interior, which you suppose agitated by the exterior. And if the interior Rays are not retained by the Texture of a Body, they will be influenced by the external Rays, and unable to repel or reflect them. If, on the contrary, you say that they reflect them, you must allow that these internal Rays are retained in the Texture of the Body, and the Substance of this Body is their fixed Point. Now if the Body be the fixed Point of internal Rays, why may it not also be that of the external?

If therefore you would have the Texture of a red Body constitute the first Principle of its Colour, it is a shorter Way of going to work, to say, at once, that it is done by reflecting the red Rays by its proper Substance, without recurring to the contradictory Circumlocution of Pores, which absorb the red Rays, to make them subservient afterwards to the reflecting Rays all of the same Nature. For, in the Supposition of a proportional Agreement, between the

the coloured Globules, and the Texture of the Body, there is a mutual Contact. If there be a Contact, there is neceſſarily a Reflexion of the Globules, which could not be admitted, and an Introduction, Tranſmiſſion, or Extinction of the others. In this Caſe then it muſt be abſolutely granted, that theſe are the Rays reflected from the very Subſtance of the Body, which convey to our Eyes corporeal Images, together with the Colours, that are peculiar to them. LIGHT.

In ſhort, were it not the Matter itſelf of Bodies which reflects Light, from whence comes it that the hardeſt and the ſmootheſt Metals ſhould reflect more Light than porous Subſtances, and Surfaces rough and uneven? Theſe laſt Bodies have more Pores, a larger Vacuum, and more Varniſh, and conſequently more Places to reflect Light from, according to Sir *Iſaac Newton*, and his reformed Diſciples. Corporeal Matter reflects Light.

The Difficulty ſtarted from the Inequalities of the Surfaces, is not a material Objection. Theſe Surfaces, in reſpect of the luminous Matter, are only a Texture of Mounds and Hollows. This we are agreed in. The whole of the Light cannot be reflected from thence regularly, that is to ſay, in the ſame Direction. We agree farther, and believe this Irregularity to be abſolutely neceſſary for the Perfection of Viſion, or the Action of ſeeing.

To view one's ſelf in a Looking-Glaſs, it is not at all requiſite that all the Rays reflect them-

LIGHT. selves in the same Direction; it is enough that they are reflected sufficiently towards our Eyes to form an Image. When I behold myself in a Glass, a thousand Persons, disposed in different Places, may have a fair View of me at the same Time. Therefore my Image must occur in these thousand Points of Sight. The Glass then reflects the Rays, which it receives from me, in Thousands and Thousands of different Directions.

These Inequalities of Directions proceed both from the Inequality of my own Surface, and the Inequality of the Surface of the Glass. These Inequalities are consequently necessary for the seeing an Object in several Places at once. If a Looking-Glass could be procured polished to such a Degree as to be void of any manner of Inequality, and able to reflect all the Rays in the same Direction, there would be but one Line of Direction, and the Image reflected could only be seen in this single Line; or rather nothing would be seen, because this Reflexion of Light would be too strong and lively. The same Inconvenience would happen, were Light reflected from beneath the Surface of Bodies without touching them, that is to say, by the Vacuum, or the luminous Varnish; inasmuch as neither this Vacuum or Varnish have seemingly any Inequalities.

Smooth Bodies differ then from others, not because they have no Inequalities, but by reason they have

have fewer. These Inequalities are Mountains very close to one another. They reflect Light from all Parts; but their Tops being almost contiguous, and at the same Time very smooth, the Portion of Light which they reflect is exceeding lively, because it is considerable, and the Reflexion of it regular and uniform.

LIGHT.

Thus when you make the Sun dart upon a Looking-Glass, the Flashes that rebound from it at an equal Angle, are only produced by the Rays reflected by the Summit of the Inequalities or Risings of the Glass, to which perhaps are joined some Rays from the Bottom of the Hollows. All the Remainder of the Light, or of the Images, which this Glass diffuses around, results from reflected Rays, and perchance reflected more than once, on the Sides of these Risings.

These two kinds of Reflexions are observed in all smooth Surfaces. For Instance, in a Picture in Oil-Colours, the Point of the direct Reflexion is termed a *false Light*; because this great Reflexion hurts the Sight, and is an Impediment to our distinguishing the indirect Reflexion, which presents in a softer manner the Image of the Object: The first Reflexion is uniform, the second has infinite Varieties.

False Light of a Picture.

The bounding about of Light absorbed and scattered in the Cube of Crystal, and the Vibrations in Proportion to which arises this extraordinary Agitation, are moreover Phœnomena that

Light agitated by Vibrations among the Surfaces of the Prism, and scattered around.

LIGHT. that are inexplicable by Attraction, and to account for which, Recourse must be had to Impulsion. It is this Light, absorbed by the Speculum, and by Prisms *, and scattered around, which forms the Penumbra, or Shade, that surrounds and confuses the Image which passes thro' these Glasses; and it is in order to extricate the Image from this Confusion, and to render it more distinct, that Diaphragms † are applied to the Glasses of Telescopes, and black Paper is wrapped round Prisms, when we make Experiments.

Refringent Reflection. These Phœnomena proceed from two Causes, *viz.* the Reflection of Light in the solid Substance of the Crystal, and the *refringent Reflection*, that is to say, the Reflection produced by the Fluid that surrounds the Crystal.

Pores in the Crystal. Whatever numerous and strait Pores may be supposed in the Crystal, the Reflexion, which Light suffers on the Surface of Glass, is a Demonstration that it strikes against its Matter in passing through it, and that it suffers also from the Reflexions in the Inside of its Substance. This is sufficient, in Conjunction with the Diversity of small reflecting Surfaces, to scatter a Part of these Rays in the Crystal. One Portion of these scattered Rays will remain absorbed and extinguished in the Crystal, another will fly off from

* A Prism is a solid triangular Glass.
† A Diaphragm here is a Ring of Pap r.

LIGHT.

from every Part of it, and Occasion the confused Light I have been mentioning.

Cause of the Reverberation of Light.

By supposing an Impulse, round a Cube of Glass, capable of repelling Light, that can have but one determinate Force, and one certain Direction, we easily comprehend, that among the Rays which have passed through the Crystal, whether directly, or after scattering themselves in it, and which have a natural Tendency to darting from it, we may easily suppose, I say, that there is an Infinity of them too feeble to get the better of the surrounding Impulse. In that Case this Force repels these Rays, diffuses them afresh in the Crystal, and dispatches them to another Surface, which they will pass thro', if their Direction is not so oblique, but that by it they will be a second Time repelled, in case their Force be inferior to that which surrounds them. It is the Reason likewise why these Surfaces repel reciprocally the wandering Rays, and scatter them partly in the Crystal, partly in the neighbouring Air. Such is the Cause of the singular Reverberation of this Light.

The Fluid which receives these Impressions of Light, and returns those reciprocal Impulsions, is elastic. These alternative Sallies of Light must consequently be produced by Accession and by Vibrations, as Sir *Isaac Newton* has observed. Besides, all our Philosophers

 hold,

LIGHT. hold, that Light consists in the Vibrations of luminous Matter, as Sound is formed by the Vibration of the Air. So that Sir *Isaac*'s Observation serves only to give ocular Demonstration of the most generally received System.

Light consists in Vibrations of luminous Matter.

The great *Newton* was sensible of all these Consequences. He has acknowledged in all this the Insufficiency of his Attraction. He had made Preparations for Experiments in Reference to this Subject, which he had not Time to execute. Those which he accomplished gave him an Occasion of forming a Train of Ideas and Conjectures; where one finds already a *Subtile*, *Æthereal*, Matter, which *fills the Heavens*, and the *Vacuum* of the Air-Pump, and whose Density, Elasticity, and Vibrations being greatest at the Circumference, but less towards the Center of the celestial Spheres, *impel*, *urge*, and *press* Bodies towards this Center, and, in short, produce that famous *Gravitation*, which is no longer an immaterial Attraction, and the celebrated *Reflection* of Light, which results no more from under the Vacuum. It is very perceptible by these Expressions, that a longer Life, and a greater Number of Experiments, would have rendered Sir *Isaac Newton* a compleat *Cartesian*. He searched sincerely after Truth, which would infallibly have conducted him to Impulsion, and its Mechanism.

Insufficiency of Attraction

The

The Mechanifm *of* IMPULSION *fubftituted in the Room of* ATTRACTION, *in order to explain all the preceding* Phœnomena.

WE have hitherto fubftituted Impulfion for Attraction; but Impulfion is a bare Term. Shall we then incur the Cenfure fo juftly imputed to the *Newtonian* Sect? It is an inconteftable Point, that the *Impulfion of a furrounding Fluid* extends itfelf a great deal better than an *Attraction* that is *immaterial* and *inherent in Matter*. But this *better* is ftill no ways fatisfactory to a true Philofopher. He requires Mechanifm. He knows very well that a Body is incapable of being moved without being impelled by fome other, and, confequently, that all Motion is caufed by Impulfion; but he would fain be acquainted with what particular Kind of Impulfion. We have hitherto talked of the Impulfion of a furrounding Fluid. It is an eafy Matter to conceive that all Bodies are encompaffed with a Fluid. But one does not difcern, at firft Sight, how this furrounding Fluid can, in certain Cafes, impel a fmall Body towards one of greater Bulk: It is this Mechanifm I am going to explain.

A folid Body differs from a Fluid, inafmuch as the former is compofed of Parts that have an intimate mutual Contact in certain Points, and keep one another reciprocally in a State of Inaction. Mechanifm of Impulfion

LIGHT. Inaction. A Fluid consists of small Parts, which, on the contrary, are disunited among themselves, and in continual Motion. This Motion, which constitutes a Fluid, I call an *Intestine Motion*. He whose Imagination would be determined by the Senses, will form a gross Image, tho' natural enough, of intestine Motion, from that of Atoms which one sees fluttering up and down in a Ray of the Sun, when it penetrates singly into a Room somewhat darkened: This Motion is in every possible Direction.

Intestine Motion, what.

A like Motion being supposed in Fluids, it must be allowed, that the Bodies they surround are of Course acted upon, in all the Points in Contact with them, by an infinite Number of little Impressions, resulting from their agitated Particles. These Impressions constitute the Principle on which Fluids act, and the Basis of the Mechanism of almost all Physical Phœnomena.

Force, in general.

Force, in general, is the Product of the Quantity of Matter, and its Velocity, or the Square of its Velocity. So that all the active Force of a Fluid depends on the Quantity of its intestine Motion, the Number of agitated Particles, and their Quantities. But without Motion all other Modifications are of no manner of Efficacy. Gun-powder acquires no Force, but in Proportion to the Motion that is communicated to its Principles by Fire.

Ethereal

Ethereal Matter, in which all Bodies float, is furnifhed with all the Requifites to make a powerful Fluid, *viz.* fubtile, numerous, folid, and brifkly agitated Particles. I call, in this Place, by the general Name of Ethereal Matter, all the Species of Matter of greater Subtilty than Air, whatever may be their Number and Diverfity. Thefe Principles, thus far, are but little different from thofe even of Sir *Ifaac Newton*; but I mean the *Newton*, forming reafonable Conjectures on the Caufes of Effects, *Newton*, the real Naturalift, and not a Man confined to mere Obfervations, mere Calculations. LIGHT. Ethereal Matter.

The Ethereal Matter, I have been fpeaking of, penetrates the Pores of Bodies in fome meafure as Light penetrates Glafs. Now Light, notwithftanding this Facility, ever ftrikes upon the glaffy Surface, as is demonftrated, by fimple Reflexion. It meets again with a like Impreffion againft the internal Particles of Glafs, when it pierces it; and it is owing to this Impreffion, that it is partly abforbed and extinguifhed in the glaffy Subftance, and that of other Bodies; that is to fay, that one Part of Light is there deprived of its Motion. In like manner, altho' Ethereal Matter enters without any Obftruction the Pores of all Bodies, it fuffers neverthelefs fome Kind of Shock againft all the Particles of Matter of which a Body is compofed.

One

LIGHT. One may draw several important Consequences from these Principles; but I am obliged to confine myself in this Place to some of the most considerable.

Ethereal Matter meets with Shocks in corporeal Substances. Therefore in that Case it must necessarily abate a little of its Motion, and of course a small Matter of its Force. The Particles of this Fluid in Contact with the Surface of the Body, undergo the same Impressions, the same Diminutions of Motion and of Force. This Portion of Fluidity consequently has less of Action and Energy, than the Particles that are at a greater Distance from the Body. Therefore the Ethereal Matter that surrounds the Body, not in Contact with it, has more of Action and more Force, than that which penetrates it, and holds it in an immediate Contact. On which Account, Matter placed between these immediate Particles and those that are more exterior, and which will receive their Shocks, will be under a Necessity of giving way to the more powerful Impressions of the exterior Particles, and will be impelled by them towards the Body, where the Action of the Fluid is in a less Degree. So that this agitated Matter will appear attracted by the Body, altho' in reality it be impelled by the Fluid that surrounds it.

This Impulsion will act parallel to the Perpendicular of the Surfaces: for they are the Surfaces themselves of the Body, which prevent the Resistance found towards the Body, and which constitutes the attractive and preparatory Principle of Impulsion. The exterior Columns of Air, where the impulsive Force resides, are likewise parallel to these Surfaces. The Impulsion therefore is itself parallel to the Surfaces, and equal in all the Points that are at an equal Distance from the Surfaces. Therefore a Body entirely subjected to such an Impulse, will be in an Equilibrium amidst the Forces that surround it, according to the Parallel of the Surfaces. It will of course be conducted by their Impulse, without inclining either to one or other of these Forces situated in the plain Parallel to the Surfaces: Consequently this Body will be impelled perpendicularly to these Surfaces.

LIGHT.

Impulsive Attraction acts parallel to the Perpendicular of the Surfaces.

When a Ray of Light falls on the Surface of a Crystal, it is found placed in the Column of the Ethereal Fluid, that is in immediate Contact with the Crystal, and has the least Force of any, as we have seen. This Ray therefore is found freed from all the superior Force of the exterior Columns of the same Ethereal Fluid, to whose Impulse it must of Consequence more or less give way, towards the Perpendicular whither this Impulse tends, and accelerated if it follows this Direction.

Acceleration of perpendicular Rays.

It

LIGHT.

Inflexion of Light.

Refraction before the Ray enters into the Glass.

It is by means of this Mechanism, that Light, which seems attracted by the Glass to which it is exposed, is actually impelled by the Fluid which surrounds this Glass *. It is by this Impulse, that this same Light is there refracted, or turned from its Road, when it passes it obliquely, as we have seen. It has also been observed, that the Refraction is by no means made in the Substance of the Glass, but that the Ray is broke before its Entrance into this Substance †; that is to say, at the Approach of the Surface, or in the first Column of the Fluid which surrounds it. In effect, were Light refracted in the glassy Substance, it would describe a Curve; because this Refraction being in that Case made successively by all the Parts of this Substance which it traverses, there would be a Necessity for each of those successive Parts to imprint on the Ray its small particular Refraction: which in the whole would cause the Ray to make a Series of infinitely small Refractions, or a Train of infinitely small Angles, and, consequently, a Curve. Whereas in the Supposition that Refraction is made in the first Column of the Ethereal Fluid that is in Contact with the Surface of the Crystal, we must conclude, that from the Entrance of the Ray into the Pores of the Crystal, after its Refraction, it follows in a direct Line,

* M. de *Voltaire*, Lib. Citat. p. 107.
† Ibid. p. 101.

Line, the Determination given it in this first Column.

LIGHT.

But why does Glass absorb Light rather than any other Matter? It is because Glass has Pores precisely formed for the Admission of Light; and that the kind of Ethereal Matter which more abundantly penetrates Crystal and other transparent Bodies, is also that which is more proportioned for its Rencounter with luminous Matter.

All Bodies have an attractive Force.

All Bodies in general have their attractive Force, inasmuch as they are all penetrated with Ethereal Matter, and surrounded with a powerful Fluid. If I present a Curtain-Rod, a Stick, a Straw, to a dripping of Water falling perpendicularly, this Water will determine itself to the Body I present to it, and will glide all along this Body at a considerable Distance from the Perpendicular.

The other Phœnomena of powerful Attraction, as that of the Diamond, Amber, Sealing-Wax, *&c.* are accounted for by the same Mechanism, and by the Proportion we assigned for the Refraction of Light. All the Differences, in regard of these Attractions, consist in the Diversity of Pores, of the Kinds of Ethereal Matter, and of the Kinds of attractive, or rather impulsive Matter, which is looked upon as attractive. What Body is there that is not now found to be electrical, or attractive? Friction and Shocks are the Means of rendering a Body electrical;

LIGHT. trical; because a greater Degree of Motion is thereby communicated to it, and consequently more Force to the Fluid which penetrates and surrounds it.

Cause of Refraction and all the Phœnomena of Attraction

In short, this Impulse of the Columns of the Ethereal Fluid surrounding solid Bodies, is not only the Cause of Refraction, but also that of all the Phœnomena attributed to Sir *Isaac Newton*'s Attraction. The very Gravity of Bodies, the Ebbing and Flowing of the Sea, the famous Gravitation of Sir *Isaac*, are so many Effects dependent on the general Principle I have been lightly touching on.

The second important Consequence I draw from the Shocks of Ethereal Matter against corporeal Substances, is, that the Effects resulting from it are in a direct Ratio of the Quantity; that is to say, these Effects are proportioned to the Bulk of Bodies, like those of Sir *Isaac Newton*'s Attraction. For Instance, Water loaded with Salt, breaks Light more than a very thin limpid Water. A Crystal, or a Diamond, causes a greater Refraction of Light than the most ponderous Water; because this Crystal is a greater deal heavier, or contains a much larger Quantity of Matter, than a like Body of Water. This is the Mechanism of the most considerable Refraction.

As all the Pores of Bodies are supplied with Ethereal Matter, there is not a single Particle of a corporeal Substance that is not in Contact with

with this Matter. The Effect that will reſult from this Contact, will therefore be proportioned to the Quantity of theſe Particles. The Quantity of theſe Particles, is what conſtitutes the Gravity of a Body. Conſequently this Effect will be proportioned to the Gravity of Bodies. LIGHT.

So that the Impulſe, or Motion, a Body will receive by the Action of the Ethereal Fluid, will be ſo much the more conſiderable, the more Subſtance that Body will contain, and the greater ſhall be its Gravity. It is in this Proportion, that the Action of this Fluid produces the Gravity of Bodies.

In like manner, the Shocks of an interior Fluid againſt a corporeal Subſtance, where it reſides, will weaken the Action of this Fluid againſt this Body, in Proportion as the Number of theſe Shocks ſhall be more or leſs conſiderable. Theſe Shocks are proportioned to the Quantity of the Subſtance. The Diminution of the Force of the interior Fluid will be therefore proportioned likewiſe to the Quantity. But the Superiority of the exterior Force of the Ethereal Fluid, is by ſo much the greater, as the interior Fluid is weaker, or has more of an attractive Diſpoſition. Conſequently, this Impulſe, which ſurrounds Bodies, is ſtill proportioned to this Gravity.

LIGHT.

Impulsion no Ways inferior to Attraction

By this means Impulsion acquires all the Advantages of *Newtonian* Attraction; and the terrible Objection of that Philosopher vanishes; who pretends to demonstrate, that an Impulse cannot act, but in relation to the Surfaces; whilst all the Phoenomena, for which he has invented Attraction, display themselves relatively to the respective Bulks. This is what he has tacked to his Attraction inherent in all the Particles of Matter. But it is evident, that Impulse has the same Advantages, without incurring the Absurdities of Attraction. It has, besides, this additional Excellence, that it accounts for a greater Number of Phoenomena.

The general Rule we have just established for the Attraction of Light, proportioned to the Gravity of Bodies, supposes that the Particles which compose the Weight of Bodies, are of the same Nature. But, if this Weight should be found consisting of Particles properer to embarrass the Motion of the Ethereal Matter comprehended in the Body; then this Matter, being more relaxed and weakened, would occasion a greater Superiority of the exterior Columns, and consequently a stronger Impulse. This Body therefore might, with a less Gravity, be endued with as great, or a greater, Degree of Attraction, than another of more Gravity. Now this is actually the Case, as to Matter composed of Particles in Motion, as Fluids are,

are, becauſe theſe Motions produce more powerful and more frequent Shocks againſt the Ethereal Matter, which penetrates theſe kinds of Bodies. For Example, Water, tho' of leſs Gravity by a great deal than Cryſtal, refracts Light but a little leſs than that does. Conſequently, Water, in regard of its Denſity, refracts Rays more than they are refracted by Cryſtal.

Among Fluids, thoſe which are furniſhed with a good deal of Oil, Sulphur, and volatile Particles, are capable ſtill of a ſtronger Refraction; inaſmuch as the Ethereal Matter is more compact, more embaraſſed by the Parts of Sulphur, and more powerfully agitated by the volatile Particles with which this ſulphurous Matter is penetrated. It is the Reaſon why Spirit of Wine produces a Refraction as ſtrong again as that which reſults from Water, tho' the Denſity of Water be far more conſiderable.

Were there ſolid Bodies compoſed of Parts as different from one another, as thoſe are which conſtitute Water and Spirit of Wine, we ſhould find, in reſpect of them, the ſame Difference of Refraction. For Inſtance, Amber, of much leſs Denſity than Cryſtal, refracts more ſtrongly than Cryſtal, in regard to its Denſity; becauſe Amber conſiſts likewiſe of a Compoſition of Parts proper to cauſe an additional Embaraſſment to the Ethereal Matter which penetrates it.

LIGHT. Another peculiar Property of impulsive Attraction, which I shall also endeavour to explain, is, that this Attraction is increased not only in Proportion to the Gravity of Bodies, but still farther, *proportionably to the Minuteness of them.* A small Piece of Crystal attracts Light more forcibly than a larger: The Reason of it is this.

The Attraction on the Anvil is produced by an Impulse of the Ethereal Fluid, which surrounds corporeal Surfaces. This impulsive Force will be therefore proportioned to these Surfaces. Now the Proportion of Surfaces is greater in small Bodies, or, what is the same Thing, small Bodies have more Surfaces in regard to their Bulk, than great ones have in respect to theirs. The exterior Columns then of the Ethereal Fluid, where the impulsive Force resides, will have a greater Extension, more Points of Contact, and, consequently, more Influence over small Bodies, than over large ones. Therefore the pretended Attraction of these small Bodies must necessarily be stronger, than that of the large; as Sir *Isaac Newton* has also observed, without being able to account for it.

This new Ratio of Surfaces does not at all destroy that of the Bulk of Bodies, which we have been establishing. That of Surfaces is derived directly from the Quantity of the Impulse, which surrounds the Body, or from the intrinsic

Value

Value of this Impulse. The Ratio of the Bulk of Bodies, is taken indirectly from the Impulse; but directly from the Weakness of the Fluid, that is within the Body; by reason of which Weakness, the Force of the surrounding Impulse increases respectively, altho' its intrinsic Value be ever the same.

LIGHT.

COLOURS.

The Nature of Colours according to *Des Cartes*.

COLOURS are either Modifications, or actual Parts of Light. They are *Modifications* of Light according to the *Cartesians*, who hold, that the Diversity of Colours depends on the manner of Light's being reflected by corporeal Substances. They are *Parts* of Light, according to the Doctrine of Sir *Isaac Newton*; who imagines that Light, or white, is a Composition of seven Sorts of Rays, *viz.* red, orange, yellow, green, blue, indigo, and violet: and that these Rays, or Globules, the Principles of the seven Original Colours, are unalterable. So that, according to him, each Colour is inseparably attached to each of these Species of Rays. And a Body is stiled red, when it reflects red Rays or Globules, and when it absorbs, or extinguishes, others. It is called blue, when it solely reflects blue Rays, or at least blue Rays in greater Number than all the rest; and so of other Colours. In short, a Body appears white, when it reflects all the seven

According to Sir *Isaac Newton*.

Colours. Kinds of Rays at once. If, on the contrary, a Body absorbs and extinguishes almost all the Rays, it is termed black; if it gives free Admission to the greatest Part of the Rays, it receives the Appellation of transparent: if it permits none to enter it, without extinguishing one Part, and reflecting the other, it is named an opaque Body.

We have seen how Rays are reflected from under a Body; how they pass thro' it; how they are there refracted. The Extinction of Rays is a Compound of all these Effects. A Ray is extinguished in a Body, when it penetrates it so as to be refracted in several different Directions, in the heterogeneous Substances that compose all opaque Bodies; to be reflected in the hollow Pores of these Bodies, and there at last to lose its Motion. A Ray passes across a Body, when this Body is so thin, that it is not of sufficient Substance to stop it in its Pores, there to refract, reflect, and extinguish it. Such is Isinglass, thin Horn, *&c.* A Body, tho' of Density, is nevertheless transparent, when it has Pores every way disposed for the Passage of Light. Of this Nature is Water, Crystal, *&c.*

Cause of the Colour of Bodies. Sir *Isaac Newton* says, that a red Body is that which reflects red Rays. In the mean while a red Glass appears such, not only at the Point of Reflection; but likewise in its transparent Parts, and even colours the Objects with

with red, that are behind it. We ought then to say, that red Glaſs extinguiſhes all other kinds of Rays, and that it reflects, and allows a Paſſage only to, red Rays. Colours.

But, according to this Principle, if I put two Glaſſes together, one blue and the other yellow, I ought not to find behind them any Colour at all. For the blue Glaſs, which I ſuppoſe before, will have extinguiſhed all the Rays, except the blue; and the yellow Glaſs behind will in its Turn extinguiſh the blue. So that there will not be a ſingle Ray behind, and, conſequently, all will be black. I am taught nevertheleſs by Experience, that theſe two Glaſſes thus joined, reflect on their back Part a green Colour, compoſed of two others, blue and yellow. Conſequently, theſe Glaſſes do not extinguiſh every kind of Ray, that is not of their own Colour. Whence we ſee, that this Syſtem, tho' very ſatisfactory and almoſt univerſally received, is not however without its Difficulties.

Therefore, when we talk of a red Ray, we do not mean that this Ray is actually coloured with red; but only, that this kind of Globule is made in a manner proper to excite in our Eyes the Senſation of a red Colour. In a Word, this Ray is not red, but the Agent or Cauſe of the Senſation of Red.

The Followers of Sir *Iſaac Newton*, if we may believe them, tell us, that this Sentiment is

Colours.

not a Syſtem, but a natural Hiſtory of Colours: wherein Sir *Iſaac*'s Imagination has had no other Part, than the Invention of Experiments proper to demonſtrate theſe Properties of Light: That he has no where aſſerted, that Light or a white Ray was compoſed of the Principles, or ſeven primitive unalterable Colours; that when he had divided by the Priſm a Ray into ſeven Colours, and having put each of theſe Rays to the ſame Proof, he was convinced, that theſe primitive Rays were indiviſible, unalterable, and, conſequently, the Principles of Light and of all Colours: In the ſame manner as Anatomiſts regard the ſimple Fibre as the Element of all the Parts of our Compoſition; becauſe this Fibre is the ultimate Term of their Diſſections.

The Inſtrument Sir *Iſaac Newton* made Uſe of to diſſect Light is the Priſm; and the different Refrangibility of Rays is a Sort of cellular Texture, or Interſtice, which conducted him to diſtinguiſh each of theſe Species of Rays.

Experiments of Sir *Iſaac Newton* on Light.

Let a Ray of the Sun enter a dark Room; receive it upon a Priſm. It will refract, and give you at the lower End of the Room an oblong Image, P. T. fig. 1, Pl. IV. made up of ſeven Rings of Colours of great Beauty; to wit, (beginning from below) a red Ring, an orange-coloured, a yellow, a green, a blue, an indigo, and a violet.

In the mean while the Ray of the Sun you receive upon the Priſm is a white gilt. And if you

Plate. V.

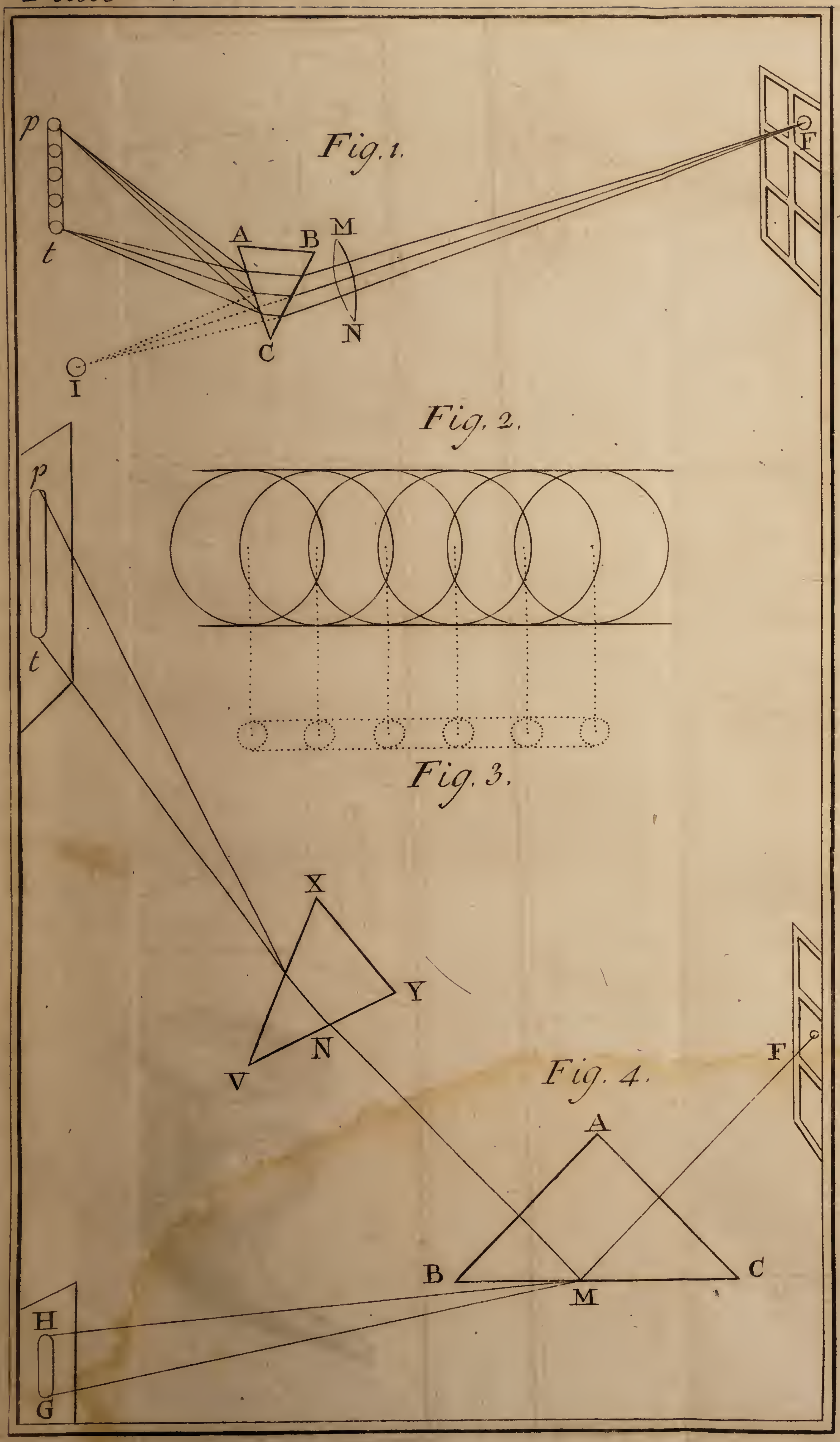
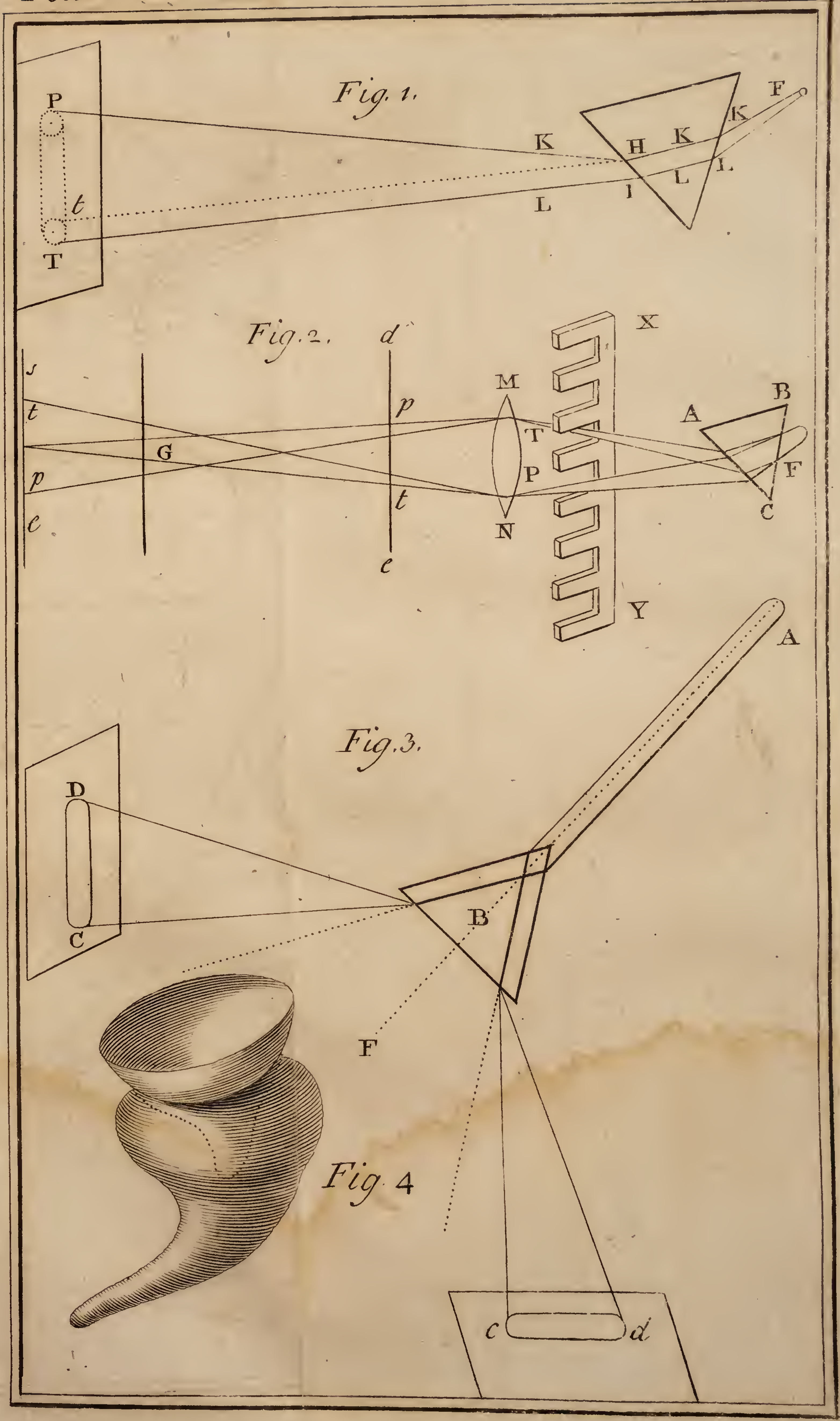


Plate. IV.



Colours.

you receive it a ſecond Time on its Exit, from the Priſm and intirely againſt the Priſm, that is to ſay, previouſly to its Diviſion, you will find it ſtill very white. Even when it is divided into ſeven Colours, if you receive it upon a Lens, M, N, fig. 2, and put a Piece of Paper to the Focus G of the Lens, in order to receive all theſe Rays centered in a ſingle one, you will farther diſcover this Ray to be altogether white. In *d*, *e*, and *s*, *e*, you have the ſeven Colours; but in *s*, *e*, they are in a reverſed Order, by reaſon of the Increaſe of the Rays produced by the Lens.

If you intercept any one of the ſeven Colours, whether in X, Y, here, or in *d*, *e*, there, of the Lens with the Teeth of a large Comb X, Y, or any other Body, the white or intire Ray G will ceaſe to be white, and will be of the Colour compoſed of the Rays that are ſuffered to paſs. For Example, if one intercepts the violet Colour, the purple, the blue, and the green, the remaining Colours, *viz.* the yellow, the orange, and the red, will produce in the Focus G of the Lens, a Ray intirely of an orange Colour. If the red and the violet are intercepted, the whole Ray G will become a ſort of green. When theſe intercepted Rays are permitted to paſs, the white is immediately re-eſtabliſhed. Light or the white Ray is therefore an Aſſemblage or Collection of the ſeven coloured

Colours. loured Rays, blended together in a just Proportion.

If the Comb X, Y, be gently passed before these Colours, one distinguishes successively all the Changes of the Colours, that are thus combined. If you pass it hastily, there appears only white; in the same manner as live Charcoal, when swung around, exhibits but a Circle of Light; because all the Impressions are made almost at once. The Sensation of Whiteness is therefore the Assemblage likewise of the seven primitive Impressions. In short, Sir *Isaac Newton*, to leave no stone unturned in order to demonstrate this Truth, has copied Nature herself, in composing a white Powder with original Colours mixed in a certain Proportion.

The first Experiment of this Philosopher *, by which a Ray is divided with the Prism into seven Colours, is by no means a new one, tho' it is the Basis of his grand Work: but those, who made it before him, were not apprized of its Consequences, acquiescing in this single Experiment, which he multiplied and varied in a thousand and a thousand different Shapes during the Space of thirty Years.

One ought to observe attentively, that, according to the Rules of Optics, the Ray, which is refracted in the Prism, and tends to form the coloured Image P, T, must not paint this Image agreeably to its actual Height. The two Rays

* It is the third Experiment of his Book.

Rays H, I, which quit the Prifm, are parallel, are equally inclined to the Surface of the Prifm, and have the fame Perpendicular. Therefore they are fubjected to an equal Refraction on paffing from the glafs Medium to Air; and, confequently, muft continue to be parallel quite to the Image P, T, and of courfe reduced in the Space, T, t.

Colours.

All that I have faid would be a neceffary Confequence, were Light a fimple Subftance, whofe Parts were all of the fame Nature, and fubjected to the fame Laws of Refraction, as was the eftablifhed Opinion before Sir *Ifaac Newton*. But the Experiment of the Prifm, all fimple as it is, is a Demonftration, that there are no other than original Rays, to wit, red, orange coloured, *&c.* which follow thefe known Laws, and that all other Rays are fubject to a greater Refraction, or are more refrangible; becaufe they are more feeble, and give way more to the Impulfe we have been fpeaking of. This Experiment concerning Reflection, proves then, that Light is made up of different Kinds of Rays differently refrangible.

Another Experiment, fimpler indeed, which I made accidentally, and which fince I have met with elfewhere, feems to point out more evidently the fame Truth.

Thro' a Hole A, Fig. 3. Pl. IV. fufficiently large, made in the Window-Shutter of a Room, dark, or not dark, let pafs a Ray of the Sun in

Colours. in order to receive it on the Angle of the Prism B, in such a manner, that this Angle divides the Ray into two equal Parts. Each Moiety of this Ray, falling upon the opposite Surfaces will produce a coloured Image C D, c d, every red Ray of which C, c, will be situated on the Side of the Axis ABF of the intire Ray, or towards the Perpendicular; whilst the other Colours will be at a Distance, so that the violet Colour will be at D, d; and that, because the red Rays of each Moiety of the intire Ray, having more Force, yields in a less Degree to the surrounding Impulse, and passes in a directer Line, and, consequently, nearer the Perpendicular, and the Axis of the total Ray.

But the seven Rays rendered by the Prism, are they actually the unalterable Principles of Light and Colours? Are they not divisible into a greater Number? Cannot one make them less compounded? For Example, green, is it not compounded of blue and yellow?

The Answer to these Queries is supplied by new Experiments.

Make a very small round Hole F, Fig. 1, Pl. V. thro' the Window-Shutter of a dark Room. Ten or twelve Feet from this Hole receive a Ray upon a Lens MN, with ten or twelve Feet of Focus. Receive this refracted Ray upon Paper I, placed at the Focus of the Lens. Immediately next to the Lens put a Prism ABC, which refracts the Light in p t; and you will have

have in this Image your ſeven primitive Colours in as many Circles, ſeparated very diſtinct from one another. Colours.

Receive this Image on a black Paſteboard pierced on purpoſe to let paſs each of theſe Circles of original Rays. Refract a-new each of theſe Rays behind the Paſteboard; and receive this freſh Refraction upon a white Paſteboard placed two or three Feet from the Priſm. You will find that this Circle changes neither its Figure, nor its Colour; that it is capable of no farther Diviſibility, but is abſolutely unalterable, how numerous ſoever the Refractions may be to which you expoſe it. It is unchangeable both in regard of Figure and Colour, becauſe each of theſe Circles conſiſts of Rays of the ſame Nature, of the ſame Colour, of the ſame Refrangibility, and which conſtantly preſerve the perfect Paralleliſm aſcribed to univerſal Light before Sir *Iſaac Newton*'s Time.

Puſh ſtill farther the Proof of theſe ſimple Rays. Inſtead of receiving them upon a white Paſteboard, receive them upon coloured Glaſſes. You will find them paſs acroſs theſe Glaſſes without the leaſt Alteration of their Colours: that is to ſay, a blue Ray, which ſhall paſs thro' a red Glaſs, will ſtill be blue behind this Glaſs; a red Ray will ſtill be red behind a yellow Glaſs, and ſo of the reſt: becauſe theſe Rays being ſimple and immutable, theſe Glaſſes muſt either totally extinguiſh them, or let them paſs ſuch

Colours. ſuch as they are. Now theſe ſolar and primitive Rays have too much Vigour and Vivacity to become extinct in a Glaſs.

He ſhould therefore have thus diſſected Light even to its ultimate Rays, to come at its ſimple and unchangeable Parts.

But is not the green Ray or Circle compoſed of blue and yellow Rays? No. For firſt, in order to a Mixture of this kind, the yellow Circle and the blue Circle ought to join and be confounded with the green. Now theſe three Circles are diſtinct and ſeparated. Secondly, form two Images of coloured Circles in the ſame Room. Let the yellow Ray of one of the Images, and the blue Ray of the other, paſs a-croſs a Paſteboard. With Priſms placed behind theſe Paſteboards make both theſe Rays fall upon the ſame Point, and they will produce no more than a green Circle. Obſerve this compounded green Circle a-croſs a Priſm, which appears oblong; while the ſimple green Circle of the ſeven Circles, ſeen acroſs the Priſm, ſeems exactly round. The Reaſon why the green Circle, compoſed of a blue and of a yellow one, appears oblong, is, becauſe it is not ſimple, but formed of two Rays that have different Degrees of Refrangibility. The green Circle of the coloured Image ſeems perfectly round, becauſe it conſiſts of ſimple Rays, Rays that are original. Thirdly, the green Circle of the coloured Image is not compoſed of a Portion

of

of blue Rays, and a Portion of yellow, is so evident, that if in the Passage of the Rays of the Prism you intercept either a blue Ray, or a yellow, or both the Rays together, as we have seen Fig. 2. of Plate IV. the green Circle exists in all Respects the same. It has therefore nothing of these collateral Rays, and is of Course a simple and an original Ray. Colours.

Conceive then that a Ray of the Sun, or of circular Light is an Assemblage of coloured Circles confused together. Suppose for a Moment that this circular Ray is a Collection of seven Counters placed one upon another, the first of which is red, the second orange-coloured, the third yellow, the fourth green, the fifth blue, the sixth of an indigo Colour, and the seventh of a violet. Now, in making this Collection of coloured Rays pass by the Prism of the first Experiment, it is just as if you threw your Parcel of Counters on a Table in order to tell them, or shew them separately, partly, at least, as in Fig. 2, Pl. V. when each of the Colours will be very distinct.

But in this first Experiment your coloured Counters are large, and not sufficiently extended. They advance besides a little one upon another; and become confused at their Extremities. These Extremities therefore form Mixtures and a Composition of Colours.

In

Colours.

In the laſt Experiment, Fig. 1. Pl. V. the Diameter of the Counters is diminiſhed by the Smallneſs of the Ray, and the ſame Extenſion is preſerved along the whole Row of theſe Counters, whoſe Centers are equally diſtant from one another, as in Fig. 3. becauſe the Refraction is the ſame. So that the ſeven coloured Counters are no more in Contact, but ſeparated and detached one from the other. Each Counter and the Colour it diſplays is perfectly ſingle and uncompounded, as in Fig. 3, and Fig. 1.

Doubts concerning the *Newtonian* Syſtem.

All I have been ſaying in relation to Colours, is the pure Doctrine of Sir *Iſaac Newton*; and I leave it to him to warrant his own Experiments. For I aver, that, how exact ſoever I have been in the Execution of his Proceſſes, I could never ſeparate the ſeven Circles of Colours of his eleventh Experiment, in the manner they are expreſſed in the firſt Figure of Plate V. It was notwithſtanding what I particularly wiſhed to ſucceed in, becauſe I looked upon it as the fundamental Experiment of the *Newtonian* Syſtem. In order to accompliſh this Point, after having ſeveral Times repeated the Experiment and ſtill failed in it, I had the Preſumption to aim at improving on even Sir *Iſaac* himſelf. According to the Principle adopted by this Philoſopher, ſaid I to myſelf, to make a regular Diviſion of the ſeven Colours, there is no Difficulty;

culty; but to receive a very ſtrait Ray on a Prifm, that will refract and ſcatter this Ray to a great Degree, according to the Length of the coloured Image. Now a Prifm with concave Surfaces, ought to give the ſeven coloured Counters at a conſiderable Diſtance from each other: For it is the Property of concave Glaſſes to ſcatter the Rays. I therefore procured a Priſm to be made with concave Surfaces, and ſeveral others with different Angles, all ſolid, and of the fineſt Glaſs of the famous Manufacture of *St. Gobin* in *Picardy*. They were formed under the Inſpection of Monſ. *Bernieres*, a Gentleman well verſed in natural Philoſophy, and my particular Friend. All this Apparatus did not by a great deal anſwer my Hopes. The Separation of the ſeven coloured Circles has ſtill remained with me the grand Work.

Colours.

I have ſeen ſince, that the moſt celebrated Profeſſors of Sir *Iſaac Newton*'s Principles, ſuch as Monſ. *de Voltaire*, and Naturaliſts the moſt dextrous at his Experiments, ſuch as the Abbe *Nolet*: Neither the one nor the other of them was happier in this Reſpect than myſelf. I was not inſenſible beſides, that Monſ. *Mariotte* too, ſo well acquainted with Experiments, had by no means ſucceeded in the Separation of the ſeven *Newtonian* Colours; but had refuted, by other Experiments, the Syſtem of the *Engliſh* Philoſopher relating to coloured and unalterable

Colours. Rays *. Monſ. *Dufay*, the late Loſs of whom the Republic of Letters exceedingly regrets, who ſo cloſely applied himſelf to Experiments on Light, did not at all ſeem ſucceſsful in this particular one. For in adopting the *Newtonian* primitive Colours, he has reduced them to three, red, yellow, and blue, of which he compounds the other four; which is a Demonſtration that he made no diſtinct Separation of the ſeven coloured Circles.

But there were two Circumſtances that effectually diſcouraged me in my Enterpriſe. Firſt, the Principle on which Sir *Iſaac Newton* founded his Experiment, is demonſtratively falſe in Fact. This Principle is, that a very ſtrait Ray, refracted by the Priſm, gives a coloured Image, as long and as extended, as that given by a large Ray; and that the Centers of coloured Circles remain at the ſame Diſtance in both Caſes †. Now it is evident, on the contrary, from the Experiment I have made a hundred Times, that the ſtraiter a Ray is, that is to ſay, the ſmaller the Hole is, that is made in the Window-Shutter of a darkened Chamber, the ſmaller likewiſe and ſhorter is the coloured Image, and the more the Centers of the Circles approach one another. The Confuſion therefore of the Circles ought to be the ſame in all the kinds of large and ſtrait Rays. Secondly, even the

* Journal des Scavans 1681.

† See Fig. 2, 3, Plate V.

Colours.

the Figure by which Sir *Isaac Newton* expresses this Experiment, gives rise to Suspicions. He every where reckons seven primitive Colours, and in this Figure he exhibits only five Circles: Are all these Things regular in a Man that actually saw the seven Colours in seven distinct Circles? Could the great *Newton* give us a Conjecture for an Experiment, he who was so reserved in regard of Conjectures? Thirty Years Exercise in a dark Chamber ought to have rendered him more dextrous at these Experiments than any body else; especially, as he was abundantly supplied with Instruments, and all other Requisites for the carrying them on.

His Principle is what embarrasses me the most. But tho' in Rigour he be contradicted by Experience, and a narrow Ray forms a short Image, perhaps this Image is still more extended, in relation to its Ray, than is the Image of a broad Ray; by which means the coloured Circles of a small Image become a little more distinct, at least, than those of the large one. Indeed one cannot be too reserved, when the Case tends to the Condemnation of so extraordinary a Man as Sir *Isaac Newton*, in what he has given in the finest and most convincing manner. His Experiment is real, if it has succeeded but once. I wish that some great Masters in Experimental Philosophy, such as the Abbé *Nolet*, would set themselves about resolving this grand

Colours. Problem. It would give me no ſmall Pleaſure to bear Witneſs of any one Inſtance of Succeſs; after which I ſhould look upon the Syſtem of Colours to be fixed even to a Demonſtration.

Altho' the Circumſtances I have been relating, ſuggeſt ſome doubt, whether the Number of primitive Colours be preciſely ſeven, they do no manner of Injury to the Syſtem of primitive and unalterable Colours in general. One may admit them without counting them, and that even in leſs Number than ſeven, as Monſ. *Dufay* has done.

But there is farther a Sect of Naturaliſts, that are neither of one or the other of theſe Parties, but imagine, with *Deſcartes*, that Colours are the Modifications of a Matter perfectly equal, and intirely uniform, and that the Colours of the Priſm are only Illuſions of Refraction. Theſe laſt are not aware, that it is demonſtrated by the Priſm, that Light is compoſed of Rays differently refrangible. Perhaps they may alledge, that the ſcattering of a Ray that produces a coloured Image, happens purely, inaſmuch as the upper ſide K, K, K, of the Ray which falls obliquely on the Priſm, Fig. 1. Plate IV. and departs from the ſame, is nearer the Surface of the Priſm, than the lower Side L, L, L; and that by this Situation the upper Side is more expoſed to the Attraction of this Surface, and to the Refraction it produces: and that therefore this upper Side, K, K, K, being

being more refracted than the lower L, L, L, the total Ray ought to become divergent, and to be lengthened in the Figure obſervable in the coloured Image, tho' all the Parts of it are equally refrangible. But let us return to the *Newtonian* Syſtem.

Colours.

Sir *Iſaac Newton* holds, that the moſt refrangible Rays are alſo the moſt reflexible.

We ſaw above, that, according to the *Engliſh* Philoſopher, the ſeven primitive Rays are unequally refrangible; and that it is this unequal Refrangibility which diſſects them, and ranges each in its proper Claſs, and Circle of the ſame Nature, from red, which is the leaſt refrangible, to the violet-coloured, which is the moſt ſuſceptible of Refraction. Sir *Iſaac Newton* pretends, that the Rays which are the moſt adapted for being refracted, are likewiſe the fitteſt for Reflection: that the violet-coloured Ray, for Example, which is the moſt refrangible of all the Rays, is alſo the moſt reflexible. Here is the Foundation of this Opinion. Receive the Ray F, Fig. 4, Plate V. upon a Priſm, the Angle of which A is a right Angle, and the Angles B, C, half ſo. Let this Ray fall obliquely on the Priſm, in order to have the coloured Image in H, G, as in the firſt Experiment. Turn the Priſm in the Order of the Letters, A, B, C, to make the Angle B of the Rays M, H, approach the more. When this Angle ſhall be inclined upon theſe Rays to a certain Degree, you will find that from the Point M there will be made a Reflection M, N,

Colours. which we above called a *refringent Reflection.* Receive this Ray reflected M, N, with the Prism V, X, Y, and you will have a new Refraction, t, p, coloured as H, G. Turn slowly the first Prism A, B, C, in the Direction A, B, C, and you will find all the Colours of the Image H, G, pass to the Image t, p, and will observe, that the violet-colour of the Image t, p, will be the first Colour that is strengthened by the Passage of the Rays of the Image H, G, afterwards the indigo, then the blue, and the red will be the last strengthened by this Transmigration of the Ray. Therefore, concludes Sir *Isaac Newton*, the violet Colour is the first reflected, and the red the last. Consequently, the most refrangible Rays are also the most reflexible.

Reasons against Sir *Isaac Newton*'s Opinion, that the Reflexibility of Rays is in an inverse Ratio of their Refrangibility.

These Consequences suppose, that this *refringent Reflection* of the lower Surface of the Crystal, and the Reflection from a solid and polished Body are absolutely the same; which Sir *Isaac Newton* was perswaded of, because it is always from a Vacuum, according to him, that Rays reflect. But, these two kinds of Reflections being somewhat different, the Laws of refringent Reflection did not seem to me to be justly applicable to simple Reflexion.

From the Experiment we have been surveying, Colours depart not from the Prism A, B, C, to go to H, G, but inasmuch as the lower Surface of this Instrument, from whence these Colours

Colours escape, is not strongly inclined upon these Tracts of Light. For, if this Surface be strongly inclined upon these Rays, those will be found pumped back as it were by the Prism, and are reflected across its Substance; because, in this Situation of the Prism, the Rays, which depart from the inferior Surface, striking too obliquely the Surface of the surrounding Fluid, have not Force sufficient to conquer the Impulsion, and escape from the Circumference of the Prism. This Impulsion therefore being victorious, pushes back the Rays towards the Prism, and makes the refringent Reflection. Colours.

So at the Time when all the Colours depart freely from the inferior Surface of the Prism, if you gently incline this Surface of the Prism upon these Rays, to make them absorb and reflect these Colours one after another, the violet is the first absorbed and reflected, and red is the last. The Reason of it is evident.

The violet Ray H borders nearest on the absorbent Surface, B, C. This Ray is likewise the most refrangible, or that which most gives way to the surrounding Impulse; a double Reason why it ought to be the first that is conquered and carried off by this Impulse. The red Ray G, on the contrary, is the most remote from the absorbent Surface. It is the strongest of all the Rays, or that which yields the least to this surrounding Force. It is therefore evident, that, on giving to this Force by

Colours. little and little, the Superiority over the Rays which pierce it; the first Rays it ought to stop and carry off by a refringent Reflection, must be the violet, then the purple or indigo, *&c.* and the last must be the red.

But there is no drawing any Conclusion from this refringent Reflection in Favour of Reflection in general. All the World knows that when a Ball is pushed upon a Surface, from whence it rebounds, the greater the Force of this Ball is, the more it is reflected. Now, according to Sir *Isaac Newton* himself, the red Ray is in the Case of the Ball pushed with the greatest Force; therefore, *cæteris paribus*, it ought to reflect more vigorously than the rest. So that for the same Reason, that the red Ray is the less refrangible, it ought to be the more reflexible. For it is only the less refrangible, inasmuch as it prevails more than the rest over the Power of Attraction, or over the surrounding Fluid. Now, the greater the Velocity is with which a Ball pierces a penetrable Surface, the more considerable is the Force with which it rebounds from an impenetrable Surface. Consequently, the less refrangible Rays must necessarily be the more reflexible.

SHADE.

Colours.

SHADE.

HOWEVER brilliant Light and Colours are, they would not form a ſingle Image, but an immenſe and uniform Lake, proper rather to dazzle than to enlighten us, without *Shade* to divide, to diſtribute, to modify them, and in ſhort, to give them all the Force we know they are endued with in regard of the Images they compoſe. *Shade* is a Diminution of Light and Colours, the laſt Degree of which is *black*, not inaſmuch as the Blackneſs of a Body is a total Privation of Light, becauſe the Body would be then inviſible, but a black is of all Bodies that which reflects the leaſt Light, as it abſorbs and almoſt intirely extinguiſhes it. A perfect black, or the total Privation of Light, is not properly ſpeaking a Thing viſible, becauſe it tranſmits nothing to the Organ, and is only diſtinguiſhed by the illumined Bodies that ſurround it: It is a Sort of Hole or Vacuum in the Body of Light.

The Art of Drawing is a good Proof that the ſole Gradation of Shade, and its Diſtributions and Mixtures with ſimple Light, are ſufficient to form the Images of all Objects, in the ſame manner as the mingling of Sulphurs, Earth, and Water with Salts, conſtitutes the Diverſity of Savours. It is the ſame thing, as to the intermixing of every Colour, in the Art of Painting,

Colours, Painting, of which Shade is ever the Ground-Work; and these Arts we all know only mimick the Operations of Light and Shade, in respect of the Phœnomena of Vision.

The ORGAN *and* MECHANISM *of* VISION.

The Eye is at once an optical Instrument, and an Organ of Sensation.

THE Eye is not only the Organ which receives the Impression of Images, it is also an optical Instrument, which furnishes these Images with the Conditions requisite to a perfect Sensation. This double Function is distributed to different Parts of this Organ. The whole Body of the Eye is a Sort of Spying-Glass of infinite Perfection, which transmits Images in an exact and compleat manner even to the Bottom of it. This Bottom is invested with Textures of Nerves, on which the Image is imprinted, and by that means the Sensation is produced, of which one of these Textures is the immediate Organ.

In order to give a clear Idea of the Structure of the Eye, and the Mechanism of Vision, let us make Use of the Instance of the dark Chamber, which the Eye in some Measure resembles.

The dark Chamber, its Use.

Shut up a Room so close as to deprive it intirely of Light. Then make a Hole in one of the Window-Shutters, and over against this Hole, at the Distance of several Feet, place a Cloth, or some white Pasteboard; and you will find, with Astonishment, that all the Objects from without

Plate. VI. p. 139.

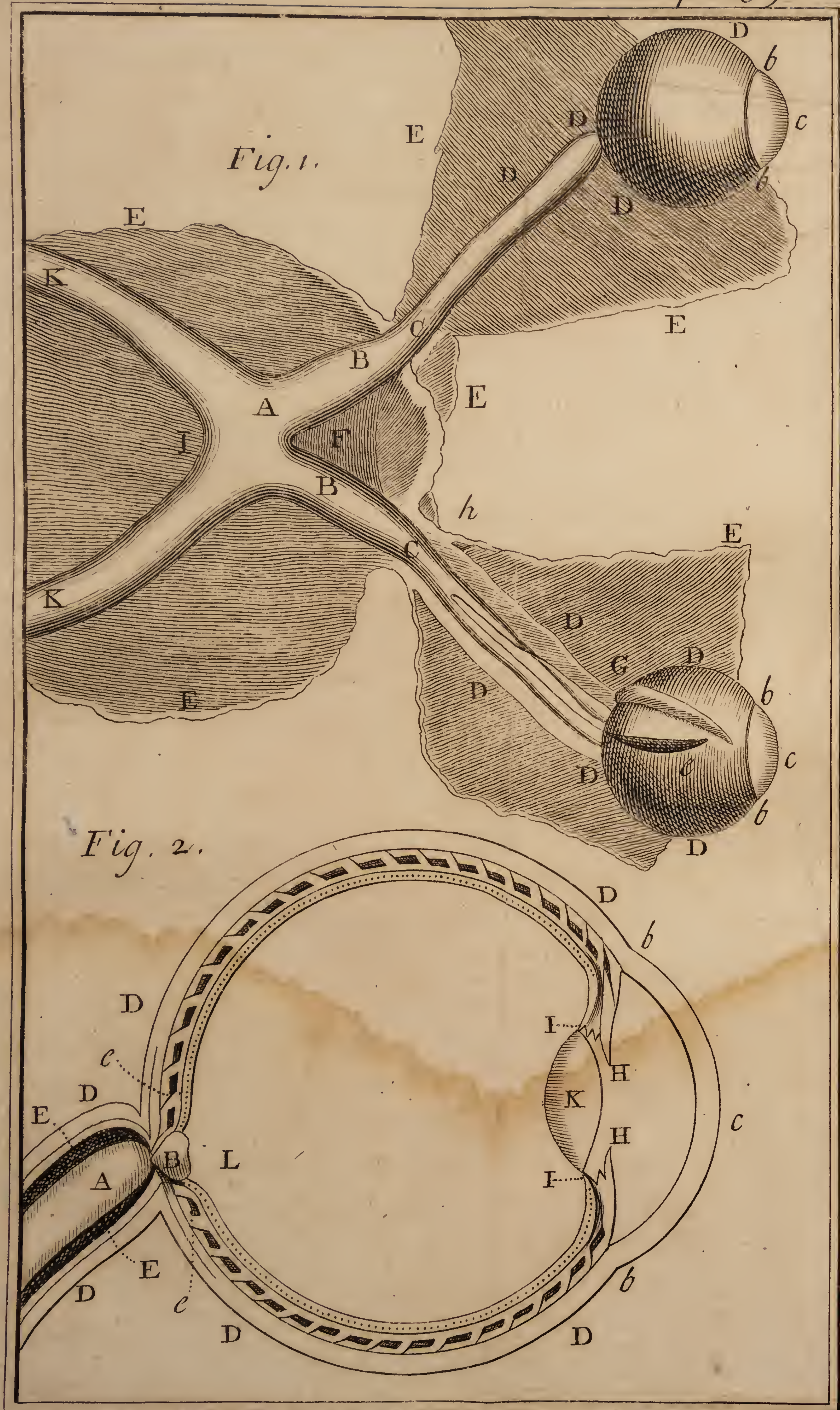
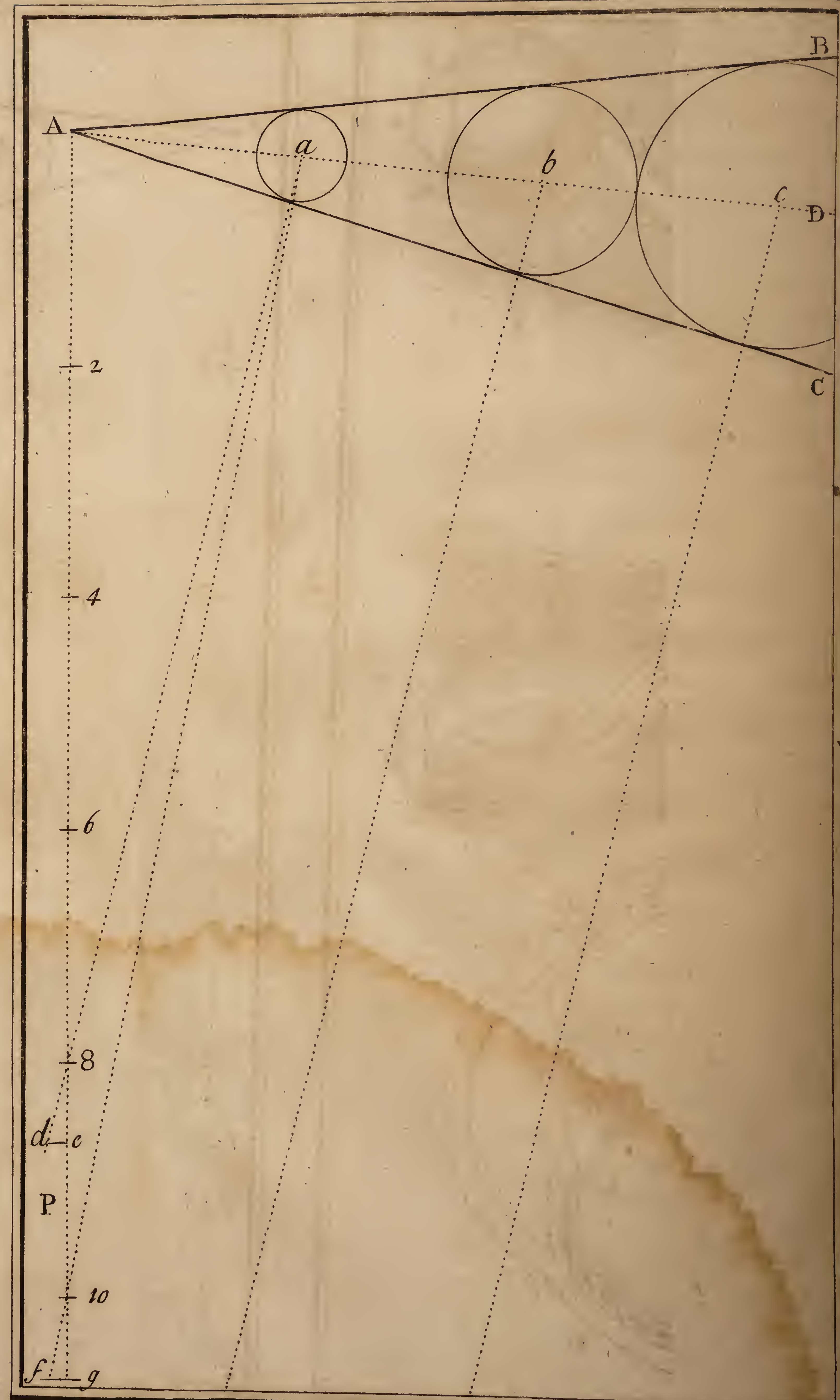


Plate. VII.



without, will be painted on this Pasteboard in the most lively and most natural Colours, tho' absolutely reversed. For Example, should the Figure of a Man present itself, it will appear with the Heels upwards. If we have a Mind to exhibit these Images still with greater Life and Exactness, let a Microscope be applied to the Hole of the Window, or a Lens, which, in collecting the Rays, forms an Image more compact and distinct. The EYE.

You may make the same Experiments with only a Box darkened within, with a Tube and a Lens placed at its Entrance; and you will have here the additional Advantage of being able to represent these Images in a state of Transparency, by closing the hind Part of the Box, where the Image is to fall, with an oiled Paper, or a Pane of unpolished Glass, or by placing in the Box a sloping Mirrour, which will reflect the Image against the top Part of it, where you have fixed your Glass. All that is wanting in Regard of this Box, to render it, as to simple Optics, an artificial Eye, is the Figure of a Globe, and having the Lens placed within this Globe.

In the natural Eye the Case is formed by supple Membranes, and the Lens by transparent Bodies and Humours equally transparent.

The Brain and the Nerves are composed, first, of a soft Substance somewhat resembling new Cheese; secondly, of two Teguments of a competent Solidity, called the *dura*, and *pia* The Structure and Formation of the Eye.

Mater,

The Eye.

Mater, each of which is manifestly double. These three Substances form all the Nerves. The *dura Mater* constitutes the exterior Coat, the *pia Mater* the interior; and the medullary Substance occupies the Center.

The optic Nerves.

The principle Nerves of the Eye, termed the Optic Nerves A B, Fig. 1. Pl. VI. make their Exit from the Cranium, one on each Side, with all this Apparatus. In the first Place they draw their Origin from those Parts of the medullary Centre of the Brain, which we stile the *Beds of the optic* Nerves; see Pl. II.

Then the two Nerves K K tend towards the fore Part of the Head, approaching again one towards the other; and unite as it were in a single Nerve A, without any Crossing or Confusion. They afterwards separate one from the other, still inclosed in the *pia Mater*, and invested with the anterior Lobes of the Brain; and, after about seven Lines of Way from their Separation, they each of them enter into a bony Hollow, that leads to the *Orbit*, the Receptacle furnished by the Brain for the Eye. There they receive from the *dura Mater* the Sheath common to all the Nerves. This Sheath confines the Nerve, and hinders it from growing too bulky and unsizable. This bony Entrance forms a Canal of about two Lines; after which the *dura Mater* is divided into two *Laminæ*, one sufficiently thin h E which lines the Orbit, the other thicker D D which continues

to

to ſerve as a Sheath to the Nerve. From the Angle h, formed by the Diviſion of theſe two Laminæ, ariſe the Muſcles of the Eye.

The EYE.

The Coat of the *dura Mater* D D, that accompanies the optic Nerve, and concurs to its Formation, is continued in the Center of the Orbit, amidſt the Muſcles, about the Space of fifteen Lines, (ſee Plate II. and VI.) after which it expands and ſwells itſelf into a Globe, much in the manner as melted Glaſs is blown into a Bottle.

At the Root of this Expanſion, between the Nerve and the Globe, the *dura Mater* forms a circular Band, by means of which it ſtrongly compreſſes the Extremity of the Nerve, and makes a Sort of Valve, which ſeems to ſeparate the Globe from the Nerve. This Band pretty much reſembles the Paper Ring applied to Teleſcopes. It is formed like the Valves of the Inteſtines, by a returning Fold of this Coat; and it is evident, that this Fold was inevitable at the Angle, which the *dura Mater* is obliged to make in order to expand itſelf all at once into a Globe *. The *dura Mater* D D, Fig. 2. on thus expanding itſelf, forms the firſt, or exterior, Membrane D b c of the Globe of the Eye, called the *Cornea*. The anterior Portion b c b of this Cornea is tranſparent, and correſreſponds with the Pupil. All the reſt is opaque.

The opaque Cornea, or Sclerotis.

Tho'

* See Fig. 1 and 2. Pl. VI.

The EYE.

The tranſparent Cornea.

Tho' the *tranſparent Cornea* be a Continuation of the *Sclerotis*, or *opaque Cornea* D, D, D, it makes notwithſtanding a Part of the ſmaller Sphere, which ſeems there added in the manner Cryſtals are to Watches. By this means it projects a little beyond the common Sphere of the Eye; which Circumſtance renders it very well adapted to its collecting a greater Quantity of Rays and Images, in regard of Objects that preſent themſelves ſideways to the Eyes.

The *pia Mater* E, Fig. 2. the ſecond Tegument of the Brain and optic Nerve, ſituated under the *dura Mater* D, expands itſelf in a Globe like the *dura Mater*, in order to form the internal Membranes, or to double the Cornea. It makes alſo before its Expanſion, a Valve, or circular Band, which ſtrongly compreſſes the Extremity of the Nerve: but it is divided into two Laminæ, one genuine and ſolid, that is applied exactly to the inner Surface of the Cornea D, where it is actually complicated and united to the other. I am the firſt, I imagine, that diſcovered this Membrane, who demonſtrated to the Academy of Sciences its Continuation with the *pia Mater*, and the very diſtinct Extenſion of it, even almoſt to the tranſparent Cornea.

The Choroides.

The ſecond Lamina of the *pia Mater*, marked by long Points in the Figure, conſtitutes what is called the *Choroides*, or *Uvea*: but this Lamina, properly ſpeaking, is only a Texture

ture of Nerves and Blood-Veſſels, that make their Exit from the inner Surface of the true Lamina I have been ſpeaking of.

The EYE.

Theſe Veſſels convey a Liquid that communicates a black or brown Colour to this ſecond Lamina. Part of theſe Veſſels and theſe Nerves open themſelves on the internal Surface of this Lamina; and there form by that means a downy or mamillary Texture loaded with the black Liquid theſe Veſſels are charged with. *Ruiſch* has made a particular Coat of this Lamina, called the ſecond Coat of the Choroides.

This, according to us, would be the third Coat diſtributed by the *pia Mater* to the Eye; to wit, one truly membranous, united to the Sclerotis, one vaſcular, termed the Choroides, and one downy, ſtiled *Tunica Ruiſchii*.

The Iris.

Towards the fore Part of the Eye the Choroides is doubled: and this exterior Complication forms what is named the *Iris* H H, in the middle of which is the Perforation of the Pupil. This Iris is furniſhed with muſcular Fibres in the Form of Rays and Circles, by means of which the Pupil dilates and contracts itſelf. It dilates itſelf in the Shade and paralytic State of the optic Nerves, by the Repoſe or ſinking of its Fibres, and is contracted when affected by Light, particularly a ſtrong one, thro' the Swelling of its Fibres, into which this ſtrong Light determines the Spirits.

The

The ORGAN.

The Corona Ciliaris. The Crystalline Humour. The inner Complication of the Choroides forms on the hind Part the *Corona Ciliaris* H H, in the Center of which is enchased the Lens of the Eye, called the *Crystalline Humour.* The *Corona Ciliaris* or *Ciliary Processes*, on a close Examination, are the last nervous and vascular Tufts, or Fringes, which expand themselves on the inner Surface of the Choroides; where they form the second Coat and the Corpus Mamillare, the principal Organ of Sensation. They are plaited at this End like the Wristband of a Shirt; inasmuch as, from a grand Circumference they were extended to before, they are reduced to a very small Circle that surrounds the Crystalline Humour. These Fringes, as they are floating, surpass a little the Bounds of the exterior Lamina of which the Iris is a Continuation.

This external Lamina is complicated * under the Ciliary Fibres, where it grows whitish and thick. It seems, in this Termination, to affect approaching to an ungulous Nature, as much as can be expected from its Delicacy; which, indeed, is the Fate of almost all Textures formed by the Parallel, and close and compact Beds of nervous Fringes.

Chambers of the Eye. The whole Space of the Eye, that is before the Corona Ciliaris II, and the Crystalline Humour

* I have separated distinctly the Corona Ciliaris from this exterior Lamina.

mour K, is filled with a limpid Water, called the *aqueous Humour*, in the Center of which swims the Iris H, H, or *Pupil.* So that the Iris divides this Space into two small Chambers, one before, that is terminated by the transparent Cornea, or exterior Glass of the Eye, b c b, and the other on the back Part a very small one bounded by the Corona Ciliaris, I I, the Crystalline Humour, K, or the Lens of the Eye, and the Iris, H H.

The EYE.

The aqueous Humour.

Next to these two Chambers, behind the Corona Ciliaris, I I, and the Crystalline Humour K, the Globe of the Eye forms a Space a great deal larger K L, than the preceding ones. This Space is all occupied by a Sort of transparent Jelly, called the *vitreous Humour*. The Crystalline Humour K is lodged in the anterior Surface of this Jelly, as the Diamond is set in a Ring.

The vitreous Humour.

The medullary and inner Part A, Fig. 2, of the optic Nerve is expanded as well as the preceding Coats, and forms a flabby Texture marked by small Points in the Plate. This Texture constitutes the inmost Membrane of the Globe of the Eye, named the *Retina*, and terminates at the Corona Ciliaris I I. This soft Substance of the Nerve, at the Beginning of its Expansion, forms the small medullary Button B.

The Retina.

The extremely fine Textures that divide the Cavity of the Eye, and make Cells for the

The EYE.

Humours it is filled with, are the ſame which in the Cavity of the Nerve divide and ſupport the medullary Subſtance therein exiſting.

Such is the Structure of the Eye diſcovered by Anatomy. But the Lights derived from Reaſon and analogous Aſſiſtances, let us a great way farther into the Nature of this wonderful Organ.

A more particular Detail of the Mechaniſm, Formation, and Uſes of the Parts of the Eye.

It has been evident all along, that every Individual Senſation is produced by nervous Papillæ; and that the Fluid which animates theſe Papillæ, receives by the Glands the Preparations and Mixtures that fit it for receiving the Senſations peculiar to each Organ. It is well known that theſe Glands and nervous Papillæ are often one and the ſame Organ; and that they ſometimes even add to the preceding Functions the Filtration of a ſenſible Liquid. This Structure is particularly remarkable in the glandulous Papillæ of the Tongue, that are at once the Organs of the Senſation of Taſte, and the Receptacles where the ſenſitive Fluid receives its Character, its Mixture, and the Reſervoirs of a filtrated Liquid neceſſary to this Senſation. The Eye, all wonderful as it is, is nothing elſe than a glandulous Papilla, of larger Size and Expanſion, and hollower than the other Glands. It is like them a triple Organ of Senſation, of Preparation of the ſenſitive Fluid, and of Filtration. The cloſeſt Examination imaginable of this nervous Papilla does not make it

in

in the leaſt degenerate. On the contrary, it reflects a conſiderable Luſtre on the Structure and Uſe of theſe Papillæ, the univerſal Organs of Senſation. This Structure and theſe Uſes, that have been hitherto a kind of Myſtery and a Syſtem, ceaſe almoſt to be ſo in the Organ of the Sight. It is a Hiſtory of the glandulous Papillæ, even ocularly demonſtrated.

The Eye.

A glandulous Papilla is a Tuft and End of a Nerve, deſtined to the Filtration of ſome Liquid. The Eye is very evidently the Extremity of the optic Nerve, expanded, and blown, as it were, into a hollow Button full of Fluids. One may trace with one's Eye the Veſſels conveying theſe Fluids, which, from the expanded Coats of the *dura* and *pia Mater* where they are interwoven, open themſelves on the Inſide of this Organ. The Size alone of theſe Veſſels viſibly evinces the Filtration made there of the contained Liquid, and the Coats and Cavity of this Organ are nothing elſe than the Prop and Reſervoir of it.

The Inſide of the Glands is the Concourſe of arterial and nervous Extremities; in which Concourſe the animal Fluid is united to a volatile Part of the arterial Blood, to enable it to diſcharge its Functions. This Union is made by Means of the nervous and vaſculary Tufts. Theſe Tufts in the Eye produce the Down of the Choroides. It is therefore highly probable, that the black Liquid with which this Down

The Eye.

is imbued, is nothing elſe than the ſulphureous Particles of the Blood diffuſed in this Texture by the Tufts of the Arteries, and loaded with the volatile Portion that is mixed with the animal Fluid, conveyed by the nervous Tufts.—Or, if you pleaſe, this black Liquid is the Dregs as it were of the Fluid, that reſults from the Mixture of the Spirits with the volatile Part of the Blood. The animal Fluid partakes in ſome Degree of the Nature of Mercury. Now Mercury, intimately united with Sulphur, forms a black Subſtance, an *Æthiops*, as every body knows. In like manner there is all poſſible Room to imagine, that the Eye preſents to us ſenſible Traces of this ſo uſeful Mixture; which we eſtabliſh on no other Baſis than that of the Neceſſity there ſeems to be for it, in regard of almoſt all the Functions, and principally of muſcular Motion.

However, this black Liquid obſervable in the Choroides is not peculiar to the Eye; we meet with it on the Inſide of almoſt all the Glands. It is viſible in the Glands of the Kidneys; for which Reaſon they are called *Capſulæ Atrabilariæ*. It is likewiſe viſible in the pulmonary or bronchial Glands. It is this ſame Liquor which is evacuated in the black Vomitings that accompany thoſe extreme Maladies, which I term the convulſive Diſſolutions of the nervous Syſtem; by reaſon that the Violence of the Depravity is ſuch, that the Inſide of the

Glands

The EYE.

Glands of the Stomach and Inteſtines is ſtript of this black Liquid. Vomitings of this Sort are more frequent in Children, becauſe the nervous Extremities which form their Glands, are ſofter and more open. In ſhort, the Colour of Negroes has no other Origin than this ſable Liquor, with which their cutaneous nervous Tufts, being very porous, imbue the Cuticle that inveſts them.

The Down of the Choroides, impregnated with the Liquid we have been ſpeaking of, forms, as we have ſeen, the inner Membrane of the Choroides. The exterior Lamina this is ſuſtained by, is in the Organ of the Sight, what the Corpus Reticulare is in the Organ of the Touch, and in that of the Taſte. In all theſe Organs, the Veſſels and Nerves, before their Expanſion into Tufts, are ſtripped of their thick Coat; and it is of theſe Spoils the Texture is formed, which in the Eye conſtitutes the exterior Tunic of the Choroides. The nervous Papillæ being ſtripped in like manner, become more delicate, and endued with a greater Senſibility; and the Texture made of their Spoils ſerves to ſuſtain the nervous Tufts and Orifices of the Veſſels that convey the neceſſary Liquids as well to the Papillæ themſelves, as to the tranſparent Humours contained in the Globe.

As far as the Choroides, the Veſſels are large enough to permit the ſulphureous Particles of the Blood, I have been ſpeaking of, to paſs along

The EYE.

with the spirituous Lymph. But, beyond this Membrane, the Minuteness of the Vessels lets only an extremely subtile Lymph escape, which forms and supplies the Humours of the Eye.

Of these the *Vitreous Humour* is the most considerable. It fills about three Fourths of the Globe of the Eye towards the Bottom of that Organ, and is condensed to a Jelly; because being embraced by all the Coats of the optic Nerve, and immediately by the medullary Part of it, the Retina, it is impregnated with a great Quantity of this enlivening Liquid; the Property of which is to give a Firmness and Consistence to the Solids and Fluids, where it occurs in Abundance.

The *Crystalline Humour*, for the same Reason, ought to have this Consistence in a greater Degree. For besides the preceding Advantages which it has in common with the vitreous Humour, its very small Circumference receives likewise by means of the Corona Ciliaris the Concourse of all the nervous Extremities of the Choroides. It must therefore be impregnated with a greater Quantity of this Fluid, and consequently acquire a larger Proportion of Consistence.

For the contrary Reason, the Liquid situated under the transparent Cornea, and remote from this great Influx of the conservatory Fluid, must fall short in Point of Consistence, and make a Fluid of an aqueous Nature.

What

What is very ſurpriſing, is the Diſpoſal of these Cauſes, to produce Effects ſo ſingularly peculiar to the Organ they compoſe. A glandulous Papilla of the Tongue is but the Extremity of a nervous Fibre. This Fibre could only make a porous Button, full of a limpid Liquid, which, indeed, was all it was neceſſary it ſhould do. But this would no ways have been ſufficient for the Organ of the Sight; more Materials were requiſite. Beſides, it is not here a nervous Fibre, but an intire Nerve, and that a very conſiderable one, which expands itſelf at once into a ſingle Papilla, and by its thick Coats forms a perfect and intire Globe, that one would almoſt imagine to be impenetrable even to Light itſelf, which, however, is not fact. The exterior Coat, which is the only one thick and ſubſtantial enough to compleat the Circumference of this Globe, is naturally diſpoſed to terminate in a tranſparent Lamina; and this Lamina occurs preciſely at the Entrance of the Rays. Becauſe, phyſically ſpeaking, it can occur only at the Extremity of this nervous Body, as the Nails can be formed no where elſe but at the Ends of the Fingers.

The EYE.

The Cornea then in this Metamorphoſis does not at all contradict its Origin, but follows the common Law of the Nerves. The farther they recede from their Beginning, the harder they grow, and compacter. The Nails are formed by the Extremities of the Nerves of the Arms

The EYE.

and Legs. These Nails are hard and transparent; and would be as transparent as the Cornea, if, like that, they were incessantly moistened with Liquids. The Cornea becomes as little transparent as the Nails, when it is once abridged of its usual Supply of Moisture. Therefore these two Parts have the same Nature and the same identical Origin.

The Rays transmitted to the Eye stand in need of being there refracted, and collected after a particular manner: and an uniform Liquid, like what is contained in all the glandulous Papillæ, could not have effected that Business agreeably to this Organ. Now the inner Substance of this large Nerve has provided for this Contingency! It is the Stream of a Fluid, which gives Consistence and Solidity to all our Parts; and its Distribution is such, that it imparts this Consistence precisely in the Order which the Perfection of the Organ demands. And in the mean Time, for such a Prodigy of Execution, what a Simplicity of Mechanism! A Nerve expanded into a Globe, its Coats distinctly spread one over another, Liquids collected under these Coats by a very ordinary Filtration; this is the whole Apparatus!

O admirable first Cause! with what Rapture ought the Mortal to be seized, who discovers demonstratively the Simplicity and natural Chain of Springs, with which such a Series of Wonders is produced!

An

The EYE.

An infirm Production, termed *Hydatides*, the Mechanism of which I have had Occasion to unravel, seemed to me to be a Sort of rough Draught of the Formation of the Eye, proper to confirm that which I have been delineating. The *Hydatides* I examined, were very brittle membranous Globes, filled with a Humour, a small Portion of which was glutinous like the vitreous Humour, and the greater Part liquid and transparent, like the aqueous Humour of the Eye. Their Size was from that of a Pea, to the Bigness of a Egg. They were contained in the Duplicature of the Membranes of the Liver and Spleen. And, from the State of the Parts affected, it seemed to me evident, that this prodigious Number of small liquid Balls were formed by the glandulous Papillæ of the Surface of these Viscera; which, retaining thro' some Indisposition the Lymph conveyed in their interior Texture, had been distended by this Lymph, and so had formed these watery Bubbles. We have already seen, that the Eye is only a nervous Papilla, that retains its filtrated Liquors. So that an *Hydatid* resembles in some Measure a defective Eye, and an Eye an Hydatid very perfect, sound, and compleatly organized. In a Word, an Hydatid, in relation to the Eye, seems to be what a Mola, or false Conception is in regard of a Fœtus.

The Eye then only differs from other glandulous Papillæ, inasmuch as this Organ is formed

of

The EYE.

of an intire Nerve, and contains in its Inside all the medullary Substance, all the spirituous Fluid of the *pia Mater*, all the Fibrillæ of this Part destined to constitute the simple Papillæ, and all the Fluids accustomed to associate themselves in the nervous Papillæ. This inner mamillary Texture is what was above described in the Choroides, and assigned as the immediate Organ of Vision, in Conjunction with the nervous Texture that sustains it, that is to say, with all the Laminæ of the *pia Mater*. This immediate Organ of the Sight has raised a great physical Controversy.

The immediate Organ of Vision.

The prevailing Opinion, that Sensations are conveyed to the very Substance of the Brain, has been the Reason why the immediate Organ of Sight has hitherto been placed in the Retina, which is an Expansion of the Substance of the Brain contained in the optic Nerve. The ingenious Monf. *Mariotte*, so accustomed to fathom the Secrets of Nature by Experiments, was even himself surprised, that the medullary Part of the optic Nerve should be incapable of Sensation *.

Experiment of M. *Mariotte*, on the immediate Organ of Sight.

This learned Naturalist was likewise a very dextrous Anatomist. He was sensible the optic Nerve was not expanded in the middle of the Bottom of the Eye, but a little above it, and on one side towards the Nose. So, willing to know the Consequence in case he made the Image

* Journal des Sçavans 1668.

Image of an Object fall directly on the medullary Subſtance of the Nerve, he placed at firſt a Piece of white Paper the Height of his Eyes, to ſerve for the Point of fixed View. He ſhut his left Eye, and determined only his Right to his Experiment. After that he placed a ſecond Paper at two Feet Diſtance from the former, on the right Side and a little lower, that the Image might fall directly upon the optic Nerve of the right Eye. After this Apparatus, he placed himſelf over againſt the firſt Paper, with his left Eye ſhut, and his right fixed on this Paper. He then ſaw them both. He therefore drew back by little and little, in order to make the Image of the ſecond Paper fall upon the optic Nerve. When he had retired the Diſtance of ten Feet, this was actually accompliſhed, for the ſecond Paper intirely diſappeared. He imagined at firſt that his having loſt Sight of the Object was owing to the Obliquity of it; but he obſerved he ſaw other Objects that were ſtill more remote from the firſt Paper, and conſequently more oblique. He repeated his Experiment, examined it from every Point, and was confirmed in the Diſcovery he had been making, that the Object diſappeared every Time the Image fell directly on the optic Nerve.

The EYE.

I have myſelf recurred to Monſ. *Mariotte*'s Experiment; which ſucceeded with me on the very firſt Trial, only with this Difference, that it

The EYE.

it was at the Diſtance of eight Feet I loſt Sight of the ſecond Paper that was placed two Feet from the firſt. Either farther or nearer than eight Feet, the ſecond Paper preſented itſelf to my View.

I did not at all confine myſelf to this ſimple Experiment. Inſtead of the ſecond Paper I loſt Sight of, I made uſe of a large Sheet of Paper, and obſerved that at this ſame Diſtance of eight Feet, I loſt Sight, in the Center of this Paper, of a circular Space of about nine Inches Diameter. I made the ſame Experiment, at all Sorts of Diſtances, but ſhall give an Account of thoſe made at three only, which will be ſufficient to eſtabliſh a general Rule. See Plate VII.

The firſt Paper, where the Point of fixed View is in A, for all the Experiments.

In the firſt Experiment, the ſecond Paper (a) is at two Feet Diſtance, as before mentioned.

The Eye (8) is at the Diſtance of eight Feet.

The dark Circle (a) is nine Inches Diameter.

In the ſecond Experiment, the ſecond Paper (b) is at the Diſtance of four Feet.

The Eye is at that of ſixteen Feet.

The dark Circle is eighteen Inches Diameter.

In the third Experiment, the ſecond Paper (c) is at the Diſtance of ſix Feet.

The Eye at that of twenty-four.

The

The dark Circle is twenty-ſeven Inches, or two Feet three Inches Diameter. The EYE.

From theſe ſeveral Experiments reſult the following Corollaries.

Generally, to make the ſecond Paper diſappear, it muſt be placed on one Side, and a little above the firſt, at a Diſtance from the Eye of about a fourth Part of that of the firſt Paper.

In Proportion as the Eye recedes from the Point of View, A, the dark Circle retires likewiſe towards D of the ſame Point A, and is enlarged to a Degree correſponding with this Diſtance.

Hence this Series of dark Circles, a, b, c, and all thoſe that are to be ſuppoſed to be between theſe, form the dark Cone B, A, C, that makes an Angle of almoſt twenty-four Degrees. Its upper ſide A, B, is almoſt five Degrees above the horizontal Line or right Angle, taking Meaſure from the Perpendicular A, P, which makes here the viſual Axis. The Axis A, D, of the dark Cone is about ſeven Degrees below the horizontal Line or right Angle. It paſſes thro' the Center of all the dark Circles, and ſo is thought to go thro' even the Center of the optic Nerve, at whatever Diſtance the Eye may be from the firſt Paper A. Conſequently, it may be determined by this Axis, how much the Center of the optic Nerve, or its Axis, is below the viſual Axis. For the more the Axis A, D, of the dark Cone

The EYE.

Cone declines below the horizontal Line, the more the optic Nerve is below the visual Axis, by reason that the Rays cross one another, and are confounded in the Eye.

One may determine likewise by these Experiments, how far the optic Nerve is distant from the visual Axis towards the Nose.

Rule to determine how far the optic Nerve is distant from the visual Axis

The Perpendicular A, P, represents the visual Axis. It is the Line according to which the Eye is placed and directed towards the fixed Point A. The pointed Lines, which from the Center of the dark Circles, a, b, c, pass thro' the Points of the Stations of the Eye, terminate in the Center of the optic Nerve, and delineate the Axis of this Nerve. These two Axes, that is to say, the visual Axis A, P, and the Axis of the optic Nerve a, d, cross one another on entring the Eye at the Point marked 8, by the first Experiment that I made; and at the Point marked 10, by that made by M. *Mariotte*. Consequently, the Opening of the Angle d, e, formed by this Crossing, is with me the Measure of the Distance of the visual Axis from the Center of the optic Nerve: and the Opening of the Angle, f, g, would measure this same Distance with M. *Mariotte*. So that since my Eye must be at the distance of eight Feet (8) to lose Sight of the second Paper, a, while *Mariotte* lost Sight of it at ten Feet Distance, (10) it is a Demonstration, that my optic Nerve recedes about a fifth farther from the visual

visual Axis, than did that of M. *Mariotte*; because the Triangle, d, 8, e, resulting from my Station, has a Basis about a fifth narrower than the Triangle, Fig. 10. g, which results from *Mariotte*'s Station.

The EYE.

To what a Minuteness Objects are reduced in the Eye.

The dark Circle is nine Inches Diameter, when the Eye is at the Distance of eight Feet; eighteen Inches, when the Eye is sixteen Feet distant; and would be thirty-six Inches Diameter, were the Eye at the Distance of thirty-two Feet. The dark Circle of three Feet is the Portion of the Image which falls upon the medullary Center of the optic Nerve. This medullary Center at the Bottom of the Eye is no larger than a small Pin's Head, or the third or even fourth Part of a Line. So that at thirty-two Feet Distance from us, a Yard of Space is included in an Image of about a Quarter of a Line. What would it be, were the Objects several Leagues distant? How many thousand Feet of Space crowded into the fourth Part of a Line! For Instance, I am on the Top of *Montmartre*: all *Paris*, that immense City, and the Extent of Plain that surrounds it, with its magnificent Palaces, are actually painted sufficiently distinct in the Bottom of my Eye. Here the Horizon comprizes about seven Leagues, and the Bottom of my Eye seven Lines. It is a League of Country for every Line, and a Quarter of a League for the fourth Part of a Line, which I before hinted.

This

The Eye.

This Reduction of seven Leagues of Country, to a distinct Image of seven Lines, is undoubtedly wonderful. It is astonishing even at first to the Imagination, tho' no ways repugnant to our Reason, nor, indeed, surpassing its Lights. Were one inclined to exceed the Truth, on this Head, and talk in the miraculous Strain, the Gasconade would be easily detected. We have seen Landscapes of a very large Extent, brought by our Painters into the Compass of a Foot of Canvas. I have seen such in the Space of an Inch, and even in the Compass of the Signet of a Ring. Nobody is ignorant what a Difference there is between the Size of a Painter's Pencil, and the Filaments of Light that enter the Eye. We are therefore soon recovered from our Astonishment, and comprehend clearly how much Nature surpasses, and ought necessarily to surpass, the Productions of Art.

A large invisible Circle surrounds every thing we see.

From the well-grounded Existence of the dark Circles, which I have been speaking of, I make this farther Conclusion, that, in respect of every thing we see, there is on each Side of them a large Circle intirely hid from us. A one-eyed Person in particular loses a considerable Part of the Objects that present themselves, if he looks on them at never so little a Distance. The Quickness of the Motion of the Eye remedies in a small Degree this Inconvenience, by taking a successive Survey of every Object; but it does not intirely repair it. The Point of Shade

Shade every where attends the Eye, and for the same Reaſon that it paſſes the Objects in Review, it muſt alſo caſt a ſucceſſive Eclipſe on ſeveral of them.

The EYE.

The only Conſequence, M. *Mariotte* had a Mind to draw from this Experiment, is to ſtrip the optic Nerve of the Function of being the immediate Organ of Sight, and the Matter ſeemed to be a Demonſtration. But independant of this very ſtriking Obſervation on the Impotence of the medullary Part of the optic Nerve, what we learn from Surgery, concerning the Inſenſibility of the Subſtance of the Brain, ſeems neceſſarily ſufficient to make us conclude, that the medullary Part of the Nerves cannot be the Organ of any one Senſation, nor conſequently of Viſion. In the mean Time this ſingle Experiment had not Force enough againſt an eſtabliſhed Opinion. A thouſand Subterfuges might have been oppoſed to it. It would, perhaps, have been granted, that the medullary Subſtance of the Brain and Nerves is inſenſible to the cutting of a Knife, but not ſo, it might have been urged, to Light proportioned to its Delicacy. Therefore Facts were neceſſary, such as M. *Mariotte*'s Experiment, to render the Opinion of the Partiſans for the Retina ſuſpected of Error; and M. *Mariotte* wanted a Perſon of M. *Mery*'s Genius and Diſpoſition, to evince, by profound anatomical Reſearches, what the Naturaliſt had began to

Sequel of the Proofs againſt the Retina.

The EYE. eſtabliſh by an optical Experiment. M. *Mery* plunged a Cat in a Pail of Water, and examined the Bottom of her Eyes; the internal Parts of an Eye, when plunged in Water, appearing more diſtinctly. He ſaw on this Occaſion, that the Retina was as tranſparent as every Humour of the Eye, and concluded from thence, that this Membrane was no more the immediate Organ of the Sight, than the cryſtalline and vitreous Humours; as the Rays pierced it as eaſily as they pierce the other Humours.

Objections and Anſwers.

Subterfuges neverthelefs are in the mean Time oppoſed to all theſe demonſtrative Proofs. Firſt, the Retina, it is urged, in ſpite of its Tranſparency, has a Sort of Opacity almoſt like that of oiled Paper. Take the Eye of an Ox, ſeparate the Coats from the Bottom of it, cloſe by the Retina; place this Eye at the Hole of the dark Chamber, and the Image of Objects will be painted on the Retina, notwithſtanding this Separation of thoſe Coats.

This little Opacity of the Retina is a Proof that it intercepts a ſmall Matter of Light, that it ſoftens the Impreſſion of it, but not in the leaſt that it is the Organ of Viſion. On the contrary, as the Retina intercepts but a very minute Portion of Light, ſuffering almoſt all the Rays to paſs, it cannot be the Organ of Sight. Becauſe an Organ ought to put a Stop to the whole Object, and fix it intirely. This

Organ

Organ therefore is rather the Membrane, on which the Retina lets all the Light that escapes itself fall, to be absolutely absorbed by this second Membrane.

The EYE.

Secondly, two Replies are framed to our famous Experiment from the dark Circle, which falls on the Center of the optic Nerve.

M. *Pecquet* asserts, that it is a Trunk of a Blood-Vessel, that occurs in this Place in the Retina, and intercepts the Action of the Ray.

But it is evident, that Light freely pierces our Solids and Fluids; particularly when they partake of such a Degree of Fineness, as we find they have in the Retina. Without this Circumstance, what Darkness would there not be in an Image! What a System it is they adopt! Because the Retina has a considerable Number of Vessels thro' the whole Extent of it; so, according to M. *Pecquet*, thro' all the Course of these Vessels, Light would make no Impression either on the Retina, or on the Choroides that is behind the Retina. In the mean while this Darkness is contradicted by Experience.

Monf. *Perrault*, in his Turn, says, that the Retina, being transparent, stands in need of the Choroides to reflect back the Rays on it, as a Looking-Glass requires Quicksilver; and that at the Centre of the optic Nerve, the Retina being unsupported by the Choroides, is like

The EYE. Glasses, whose Quicksilver had in some Part been peeled off.

This Academist compares the Choroides to the Quicksilver of a Looking-Glass, whereas it precisely produces a quite contrary Effect. The Office of Quicksilver is to make a lively Reflection of Light; the Choroides, on the other Hand, is a black Down, which totally absorbs this Light, and consequently can remit no Sensation of it to the Retina. He is obliged to own, that, where the Choroides is defective, there also Vision fails; and that thus the Choroides is an Organ as essential to this Sensation, as Quicksilver is to the Effect of the Looking-Glass, which is the Reflection of Images. I admit the Comparison in this Instance. It is the Quicksilver alone that reflects the distinct Image we believe we see in a Glass; it is that alone, which produces the intire Effect of the Mirrour, the Glass of which serves only to fix the Quicksilver, and to let the Rays pass. In like manner, it is the Choroides that performs all the Function of Vision, and that is the Seat of this Sensation; and the Retina is no more than the Glass that lets the Images pass. What other essential Function can be attributed to the Choroides in Vision, than that it should be the immediate Organ of it?

The Choroides is the immediate Organ of Sight.

Besides, in the Choroides are assembled all the Qualities requisite to form the Organ we are in quest of. It is a Continuation of the *pia Mater*,

Mater, which we diſcovered above to be the real general Organ of Senſations. The Choroides is ſolid, elaſtic, and extremely ſenſible. It is furniſhed with a Sort of black Down intirely adapted to abſorbing of Rays, or Images, and conſequently receiving the whole Impreſſion of them, and that diſtinctly. We above obſerved, that the Papillæ of the Tongue abſorb the ſavoury Juices; that the Inſide of the Noſe retains the odoriferous Vapours, *&c.* It is almoſt the general Structure in the Organs of Senſation, and there is no one where this Structure is more eſſential, than in the immediate Organ of Sight. Becauſe in caſe this Organ had not abſorbed the Image, and reflected it, this reflected Image had been ſcattered thro' this whole Concavity, all the Parts of this Concavity had produced ſimilar Reflections, and there would have been, all thro' the Organ, a ſtrange Confuſion of Rays, and of Impreſſions, without any Image, or diſtinct Senſation. It is partly for this Reaſon, that old People, in whom the black Liquid of the Choroides falls ſhort of its fine ſable Colour, diſcern not Objects ſo clearly as formerly, but with a Sort of Confuſion. The Choroides therefore is the ſole Membrane of the Eye proper to conſtitute the immediate Organ of Viſion.

The EYE.

When we would examine the Goodneſs of an Eye, we place the Perſon over againſt a fine Light, and cloſe both Eyes. We then ſuddenly

The EYE.

open the Eye we have a Mind to examine. We next remark the Motion the Iris makes on the Entrance of Light into this Organ. If it contracts itself a good deal, the Eye is very good; if but a little, it is an evident Sign it sees but feebly; and should it remain immoveable, it is absolutely deprived of Sight.

A good Eye contracts its Pupil, by reason the immediate Organ of Vision is attacked by a lively Light, that stimulates it, and determines its Fibres to shorten themselves. The bad Eye continues immoveable, because a bad Eye is that which is no longer sensible of the Impression of Light; which Insensibility is the Reason why it is not excited to a Contraction of its Fibres. It is therefore the same Organ, which perceives the Impression of Light, and that contracts its Fibres in Consequence of it. Now the Iris, which contracts itself likewise, is the Continuation of the Choroides, and has no manner of Connexion with the Retina. Therefore the Choroides is the immediate Organ of Sight.

It sometimes happens, that, in an Eye that is lost, the Iris will have a small Motion, on opening the sound Eye to a glaring Light. The Iris of the lost Eye contracts itself on that Occasion thro' the Sensibility of the sound Eye, which determines a small Portion of the Fluid that causes the Motion to flow in the Nerves of the other, where some Pipes of this Fluid remain still open, tho' all the Canals of the sensi-

tive

Plate. VIII.

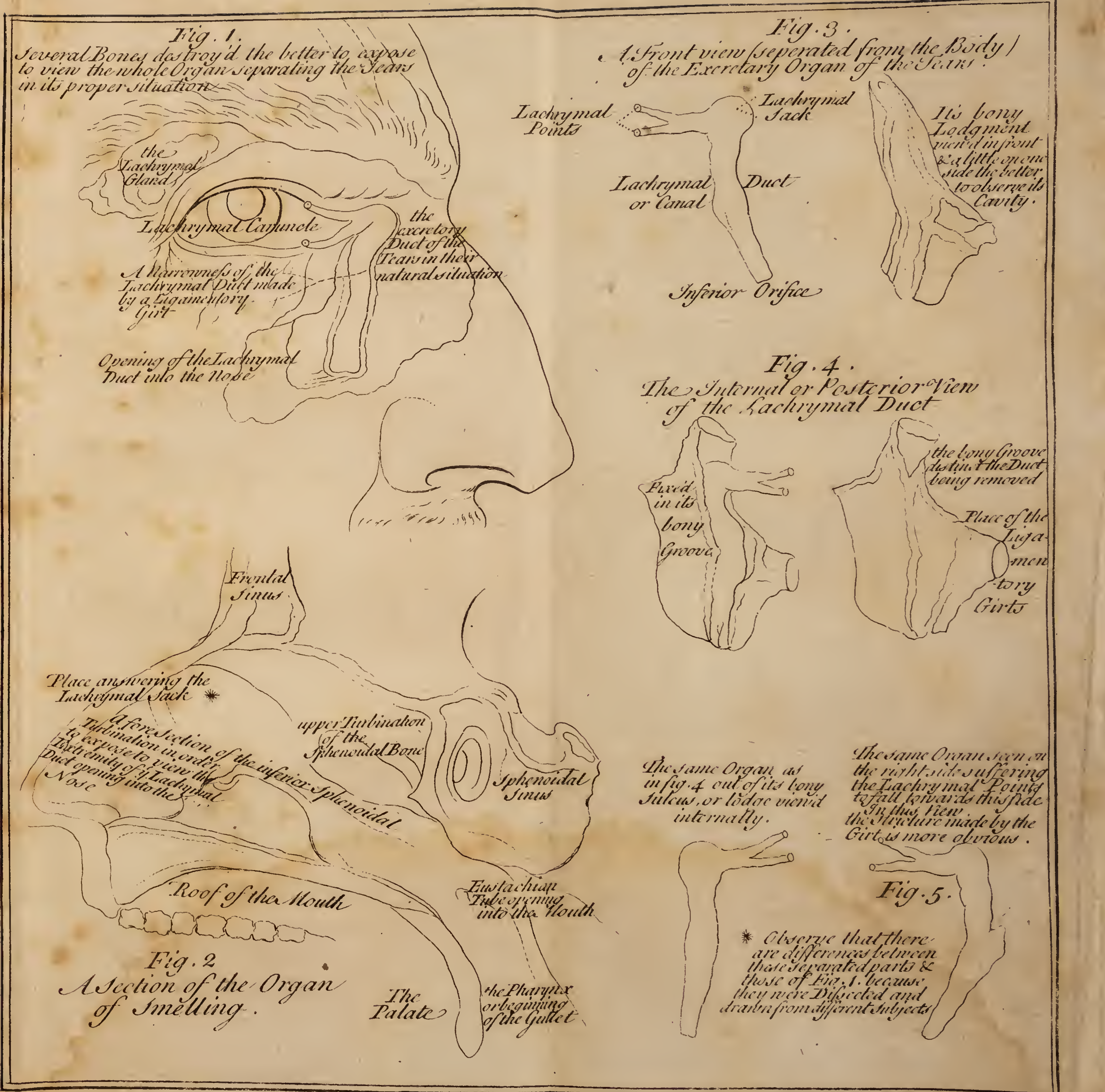


Fig. 1.
Several Bones destroy'd the better to expose to view the whole Organ separating the Tears in its proper situation
the Lachrymal Gland
Lachrymal Caruncle
the excretory Duct of the Tears in their natural situation
A Narrowness of the Lachrymal Duct made by a Ligamentory Girt
Opening of the Lachrymal Duct into the Nose
Fig. 3.
A Front view (seperated from the Body) of the Exeretary Organ of the Tears.
Lachrymal Points
Lachrymal Sack
Lachrymal or Canal
Duct
Inferior Orifice
Its bony Lodgment view'd in front & a little on one side the better to observe its Cavity.
Fig. 4.
The Internal or Posterior View of the Lachrymal Duct
Fixed in its bony Groove
the bony Groove destin'd the Duct being removed
Place of the Ligamentory Girts
Frontal Sinus
Place answering the Lachrymal Sack
A fore Section of the inferior Sphenoidal Turbination in order to expose to view the Extremity of ye Lachrymal Duct opening into the Nose
upper Turbination of the Sphenoidal Bone
Sphenoidal Sinus
Roof of the Mouth
Eustachian Tube opening into the Mouth
Fig. 2
A Section of the Organ of Smelling.
The Palate
the Pharynx or beginning of the Gullet
The same Organ as in fig. 4 out of its bony Sulcus, or lodge view'd internally.
The same Organ seen on the right side suffering the Lachrymal Points to fall towards this side In this View the Structure made by the Girt is more obvious.
Fig. 5.
* Observe that there are differences between these separated parts & those of Fig. 1. because they were Dissected and drawn from different Subjects

The EYE.

tive Fluid be intirely ſhut up; becauſe thoſe are of another kind, and of a conſiderably finer Texture, as we have ſeen.

The Accidents, which befal the Eyes, are farther Proofs on the Part of the Choroides. In caſe an Inflammation, or painful Tenſion, affects the Eye, the immediate Organ, endued thereby with too great a Senſibility, finds itſelf hurt by the ordinary Light, and ſufficiently agitated by the moſt feeble Rays, as we have ſeen by the Obſervations of thoſe Perſons, who can diſcern Objects in the dark. But, of all the Parts of the Bottom of the Eye ſtruck by luminous Rays, the Choroides alone is ſuſceptible of Pain, Tenſion, and Irritation; inaſmuch as the Retina is only a ſoft and inſenſible Subſtance. Therefore the Choroides is the immediate Organ of Viſion.

Uſe of the Retina.

To what Purpoſe then ſerves the Retina? It ſerves, firſt, to give to the vitreous Humour, and the Cryſtalline it embraces, their remarkable Conſiſtence. Secondly, to convey to the Corona Ciliaris, the Fluid that is the Principle of Action, purſuant to the ordinary Uſe of the Center of the Nerves, and of their medullary Subſtance, which conſtitutes the Retina. Thirdly, to perform on the Choroides the Function attributed to the Cuticle that covers the Papillæ of the Organ of the Touch, or to diſcharge the Office of the porous Membrane covering the glandulous Papillæ of the Tongue.

The Eye.

That is to ſay, the Retina receives the Impreſſion, moderates it, and fits it, if I may be allowed the Expreſſion, to the Uniſon of the genuine Organ. But, in receiving this Impreſſion, it is no ways ſenſible of it. The Image is repreſented on the Retina, as on an oiled Paper. It is not the oiled Paper that diſcerns the Image, it is the Eye, the Organ that is behind the Paper.

Let us quit for a Moment the Inſide of the Globe of the Eye, and ſurvey the Machines that are diſpoſed around this Organ for the Perfection of its Functions.

The Glaſs, which makes the Entrance of the Globe of the Eye, is not a ſolid Cryſtal. It is, it muſt be owned, a hard and poliſhed Membrane, but it is ſtill a Membrane, and owes all its Smoothneſs and Tranſparency not only to the aqueous Humour it contains, but alſo to another limpid Water that inceſſantly moiſtens it without, and exactly fills its Pores. Deprived of this Water, the tranſparent Cornea being expoſed to the Air grows dry, ſhrivelled, tarniſhed, and ceaſes to let the Rays paſs. This Water ſo eſſential to the Tranſparency of the Cornea, and to Viſion, is the Tears.

Organ of the Tears.

For the Source of this Liquid is aſſigned a complicated Gland, ſituated on the external and upper Part of the Eye, called the *lachrymal Gland* *.

The

* Conſult, on the Head of this whole Deſcription, the Figures of Plate VIII.

The Tears are ſhed on the fore Part of the Eye by very fine Conduits; and the frequent Motion of the Eye-Lids ſcatters them, and by that means waters all the poliſhed Surface of the Eye. They are afterwards conveyed towards the Angle pointing to the Noſe, or the grand Angle, by the twinkling Edges of the Eye-Lids, which ſeparately do the Office of a Gutter, and jointly the Office of a Canal, and at the ſame Time that of a Piſton or Sucker of a Pump.

The EYE.

On each Eye-Lid towards this great Angle, where the Tears are conveyed, we meet with a Sort of ſmall Reſervoir, the Orifice of which is termed *Punctum Lachrymale.* Each of theſe minute Canals are united at the great Angle with a common Reſervoir called *Saccus Lachrymalis.* This Bag is attended by a Canal, named the *Lachrymal Pipe*, which deſcends lodged in the Bones even to the Noſe; where it diſperſes the Tears that concur to moiſten this Organ, when they flow not in too great Abundance. But, on weeping, there is a Neceſſity of frequently blowing the Noſe, in order to diſembarraſs it of the Tears, which there flow at that Time in too great a Quantity.

The Muſcles of the Eye, their Uſe, and Origin.

It was not at all ſufficient, that the Globe of the Eye ſhould be watered in order to preſerve its Tranſparency and Beauty; it was neceſſary likewiſe that theſe Teleſcopes of the Soul ſhould

be

The EYE.

be directed towards the Objects we would take a View of; and that they fhould be dilated to receive diftinctly the Images of neighbouring Objects, and contracted for the receiving thofe of Objects at a Diftance, for Reafons we fhall fee by and by. Now all thefe refpective Motions depend on fix Mufcles, furrounding the Globe of the Eye *. Four of them direct it in its ftrait Motions, upwards, downwards, and fideways. Thefe four principal Mufcles, acting in concert with the two others, perform the oblique Motions.

Thefe Mufcles rife from the Circumference of the optic Hole at the Bottom of the Orbit, thro' the Angle formed by the Divifion of the two Laminæ of the *Dura Mater*; one of which of confiderable Thicknefs, invefts the optic Nerve, and the other, very fine, lines the Orbit, as has been already hinted. Thefe Mufcles do not, as is generally the Cafe, derive their Origin from fome Bone. Their tendinous, or rather nervous, Beginning, is vifibly a Part, or a Production, of the exterior Lamina of the *Dura Mater*; which is only of that Thinnefs, becaufe thefe Mufcles are produced at that Membrane's Expence: which, I make no manner of doubt, has produced likewife the Orbit, lined and nourifhed by its exterior Lamina. For to nourifh a Part, to give it Accretion, and to form it, feem to me three Things confequent to one

The Bones and Mufcles are the Production of the *Dura Mater*.

* See Plate II.

one another. What the *Dura Mater* does in regard of the Eye, it performs in reſpect of all the reſt of the Machine. It accompanies the whole nervous Syſtem, and lines all the Bones under the Name of the Perioſteum: and it is from theſe Perioſtea, that the Muſcles take their Riſe. It is the Reaſon, why Parts ſupplied with the moſt ſubſtantial Nerves, as the Thigh, are furniſhed likewiſe with the moſt conſiderable Bones and Muſcles. Ours is analogous to the Formation and Accretion of Vegetables. One ſole Principle extended, unfolded, and varied, forms every Species of Parts. From the Root of the Plant ſprings the Trunk, the Branches, the Leaves, Flowers, Fruit, and their reſpective Parts. From the Brain and Nerves is every thing formed in Man. His Mechaniſm is of a more complicated Nature, but ſtill it is really Mechaniſm.

The EYE.

All Parts of the animal Spring from the Brain.

Generally all the Muſcles of the Eyé correſpond in their Motion, and determine at one and the ſame Time the Axis of each Eye towards the ſame Point, towards the ſame Object; and this ordinary View is called a *direct Sight.* Sometimes the Eyes are in ſuch a State, that there is no directing both of them in a ſtrait Line towards the Object they are fixed on, which Circumſtance is termed Squinting. This Defect proceeds from the Equilibrium being broken among the preceding Muſcles, whether by Accident, or determinately. The Equilibrium

Squinting Eyes.

The EYE.

brium is destroyed among the Muscles of the Eye, first, by reason that one of the Muscles is weaker than the rest, occasioned either by a paralytic Disorder of the Nerves, or by a Sort of Sprain of this Organ consequent to some violent Motion. Secondly, Squinting arises likewise from one of the Muscles contracting itself in a greater Degree than the others, thro' an acquired Habit of forcing the Eye in the Direction of this Muscle. This is the most ordinary Cause; and it is thus that Infants in the Cradle, excited by some Object or other to turn an Eye strongly sideways, contract this ill Custom of Squinting. We shall assign hereafter an additional Cause of this Defect.

Let us see, in the mean while, how the Images of external Objects come to be painted in this wonderful dark Chamber, accommodated with its Lens's, and a Texture, that not only receives these Images, but even perceives their Impression.

How Objects are painted in the Bottom of the Eye.

We have seen, that the Action of Light consists in the Vibrations of this Fluid excited by luminous Bodies, and reflected by Bodies visible. A Body is not seen, but inasmuch as it reflects these luminous Vibrations back to our Eyes. It is only the Sun, and luminous Bodies, that become Objects of Vision by Vibrations immediate and without Reflections. These Vibrations, reflected by illuminated Bodies, are quick and lively, when they shoot from the Surfaces of Bodies, which reflect a great deal of

Light;

Light; or that are at the regular and direct Point of Reflection, explained p. 100, &c. These Vibrations are feeble in Proportion as the Reflection is more indirect, more oblique, and less supplied with Rays; and it is this more or less of reflected Light, which forms the Image of Bodies.

The EYE.

For the Parts of the Surface of Bodies, which we receive the regular Reflexion of, constitute the luminous Points of their Images. The others, which dart on us a more or less oblique Light, form the Gradations, Mixtures, and Shades of these Images. In short, Light delineates on the Choroides, as we delineate on a black Paper, in Crayons, white, grey, &c. We put white, that is, a great deal of Light, in those Parts of the Piece which ought a good deal to project, and appear in a strong Light. Grey, or, in other Words, a small Portion of Light is placed in the Parts, which ought to project less and appear more obscure; and, in short, the Paper is left all black, that is, no Light at all is displayed on the Places that should be intirely dark.

How the Image of an Object occurs in all the Points of Space that surround it.

In order to form an Idea how a Body diffuses its Image to all Distances, and in all the Points of Space that surround it, we must look upon all the Particles a visible Body is composed of, as so many small pyramidal Mountains, every one of which scatters a Sort of Atmosphere of Rays towards all the Points of Space with which this Part of the Body corresponds.

Each

The EYE.

Each Particle or each Point of the Body making a like ſcattering of Rays, all theſe Rays muſt neceſſarily croſs one another, meet one another, and unite in all the Points of Space that ſurround the Body. Now as from all the Points of Space ſurrounding a Body, there is effected a Union of Rays reflected from every Point of the Object, there is alſo produced an Image of this Object. For the Image of an Object is nothing elſe than the Union and Aſſemblage of Rays reflected from all Points of the Surface of this Object. In order to give a ſenſible Idea of this Scattering, Croſſing, and Union of Rays, see Fig. 1. where we have taken only three Points of the Object, and have ſcattered of thoſe but a few Rays, not to embroil and confound the Figure. All the Points, o, of the Circumference of this Object, where the three Sorts of Rays unite, are thoſe where the Object is viſible. Now naturally, this Union is in all the Points of this Circumference, as the Number of ſcattered Rays is in a manner infinite.

I conceive, you will tell me, that when the Rays of the Sun from the South go to ſtrike an Object placed in the North, my Eye, ſituated Southward of this Object, will receive its Image. But how ſhall I receive this Reflection and this Image, if the Object be between the Sun and me? And yet, notwithſtanding, I do not at all ceaſe to ſee it in this Situation.

You

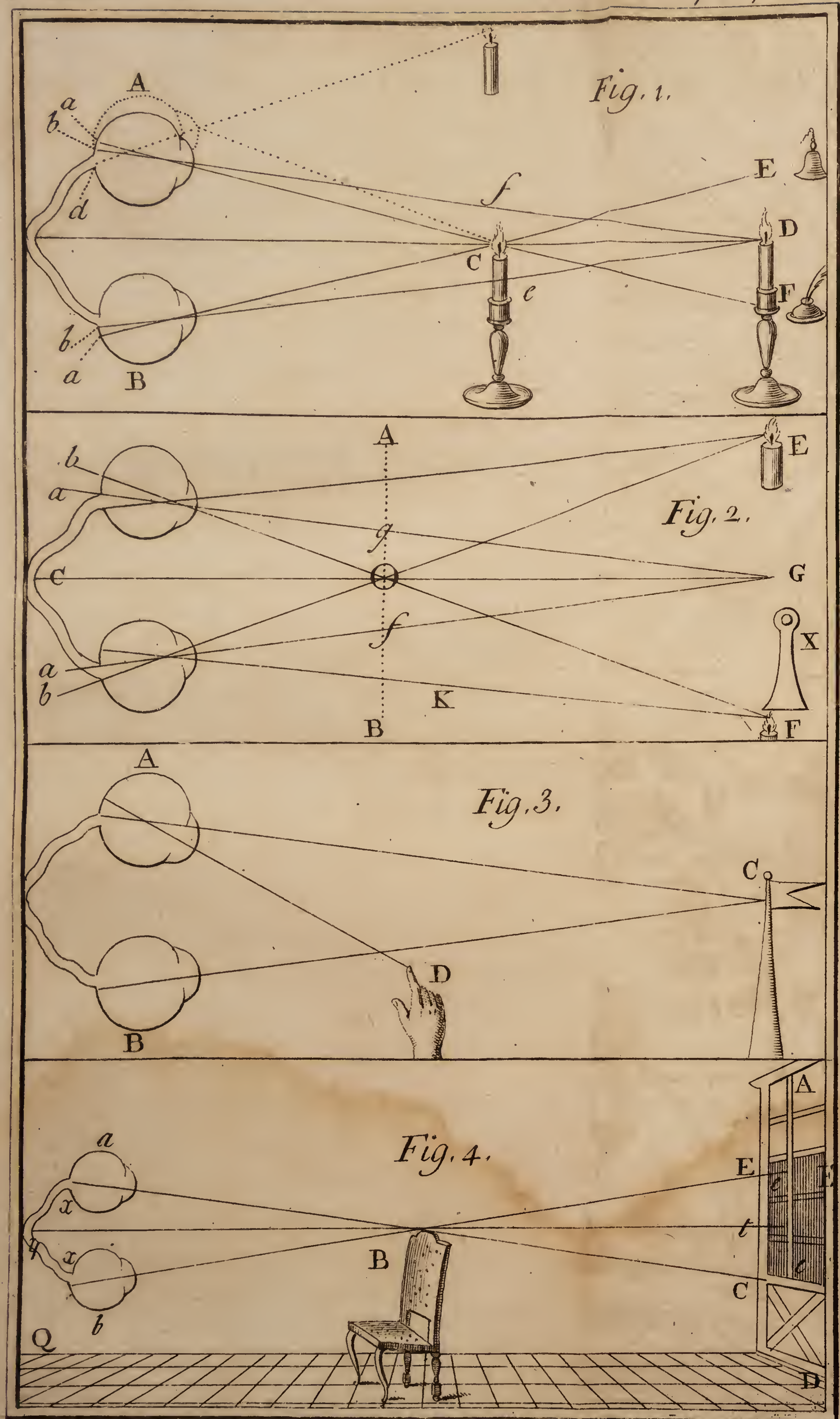


Fig. 1.
A
a
b
d
E
f
D
C
c
F
b
a
B
Fig. 2.
A
E
b
a
g
C
G
f
X
a
b
K
B
F
Fig. 3.
A
C
D
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Fig. 4.
A
a
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t
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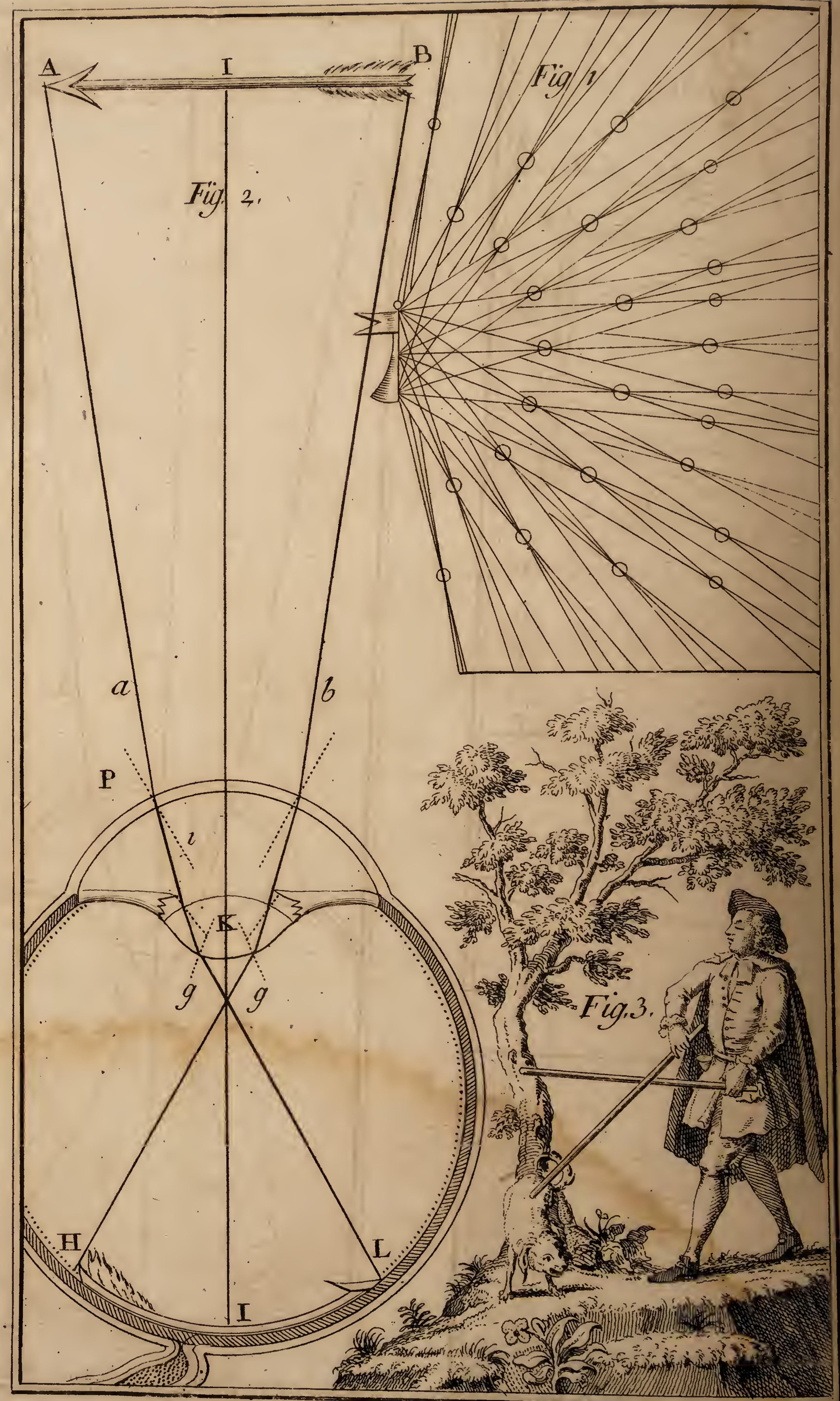
A
I
B
Fig. 1
Fig. 2.
a
b
P
i
K
g
g
H
L
I
Fig. 3.

The EYE.

You ſee it: Therefore you receive the reflected Rays of it. You do not receive the immediate Reflection of the Rays of the Sun, but that of the Rays, which, having paſſed this Object, and having been ſtruck by other Bodies, the Air, and perhaps yourſelf, have been reflected from thence towards this Object, which tranſmits them to you in its Turn. For altho' the Action of the Sun, and of all luminous Bodies, has but one ſole Direction, yet Objects reflect Rays in all Directions, and from every Point of their whole Circumference. Becauſe this firſt Direction, imprinted on Rays by luminous Bodies, is varied in a thouſand and a thouſand other Directions, by the innumerable Reflections which theſe Rays undergo from all the Bodies, and every kind of Matter, that occurs to them.

What arrives to the Image that paſſes thro' the Eye.

Let us take one of theſe Points, where theſe three Sorts of Rays croſs one another, and there place an Eye, Fig. 2, Plate IX. The Ray A, a, that darts from the Point of the Arrow, A, B, in paſſing from Air to the tranſparent Cornea and aqueous Humour, paſſes from a leſs denſe Medium to one that is more denſe. It muſt therefore be refracted in approaching the Perpendicular, p. 1; the inferior Ray, B, b, does the ſame. The Rays approach one another, and are collected in a leſs Space in order to paſs thro' the Pupil.

In

The EYE.

In piercing the Cryſtalline Humour, K, they are ſtill more compact by the ſame Law. In going from the Cryſtalline Humour, the Rays paſs to the vitreous Humour that is a leſs denſe Medium, and there ought to be refracted on receding from the Perpendiculars g, g; but, receding from theſe Perpendiculars, which have a Direction oppoſite to the former Directions, the Rays continue to approach one another, and are collected towards the Axis of the Eye, to the Bottom of which they go to convey their Impreſſion, H, I, L. This Impreſſion is made in a reverſed Direction. The Ray, A, a, falls in L on the oppoſite Side, and the Ray, B, b, paſſes alſo on the other Side H: becauſe theſe Rays croſs one another conformably to what we ſee in the Experiment of the dark Chamber. There is only the direct Ray I, K, I, which regularly follows the viſual Axis, and is not at all refracted, becauſe it is perpendicular to the Cornea, and to the whole Globe.

Objects are inverted at the Bottom of the Eye.

If the Experiment of the dark Chamber does not carry with it ſufficient convictive Evidence, take the Eye of an Ox, its Bottom ſtript of the Sclerotis and Choroides in ſuch a Manner, that the nitrous Humour is only covered by the Retina. Place this Eye over againſt two Candles. You will ſee thoſe Candles painted in a reverſed Order on the Retina, and will obſerve that the Candle on the right Side falls on the left Side of the Bottom of the Eye. Or, if

if you place one above the other, you will ſee that the upper Candle will be painted on the lower Part of the Bottom of the Eye, and that the lower Candle will be painted on the upper Part of the ſame Bottom. A Fact you may eaſily be convinced of, by removing ſucceſſively each Candle in order to take an exact Survey of them.

The EYE.

In the mean while, if we place ourſelves once more on the Top of *Montmartre*, and take a Proſpect of the vaſt and ſuperb Horizon that ſurrounds *Paris* and its Suburbs, the aſtoniſhing Reduction of ſeven Leagues of Country to ſeven Lines at the Bottom of the Eye is but a common Effect, in compariſon to what falls out at the Point where all the Rays, that convey to us this Picture, croſs. The Rays that compriſe the Picture of all *Paris*, thrice of the Compaſs of all *Paris*, are united, not in ſeven Lines, but in a ſingle Point. This is wonderfully ſurprizing in the firſt Place. This prodigious Quantity of confuſed Rays loſes, in this ſuppoſed Confuſion, neither its Direction, nor Colour, nor Force. All theſe Rays are ſeparated afreſh, and approach the Bottom of the Eye as diſtinctly as if they had never met; an Effect ſtill more aſtoniſhing. For, in ſhort, Matter is impenetrable. How therefore can Rays, tranſmitted from ſeven ſquare Leagues, keep together in a Point, in a Pin-Hole, thro' which I would ſee this Plain, and that without being in Contact, without any

How the Rays of a whole Plain may croſs one another without Confuſion in the Pupil.

The EYE. mutual Collifion, or the leaft Interruption to one another imaginable? I own, I do not apprehend it. Becaufe I have no Apprehenfion but of Things that bear fome Refemblance with others I have feen; and it is certain, I could never fee even in Light itfelf a Phœnomenon of this kind. It is a Fact, notwithftanding, true, real, and natural; and confequently, tho' I have not an Apprehenfion of it in the manner I have of large Objects, I can yet conceive it, and form to myfelf an Idea of it.

It is ufual enough to fay, that all the Rays of a Plain come to penetrate one's Pupil; and from thence it is furmifed, that Light is a penetrable Matter, a Matter that is equivocal. But this feems to me to be a Sort of Impofition. For it is to be remembered, that Bodies do not actually tranfmit Rays to our Eye, but only excite Vibrations in an Ocean of Light; and that thefe Vibrations are communicated to the Light that refides in our Eye. A whole Plain therefore does not tranfmit Rays to the Eye, but a whole Plain communicates its Vibrations to the Light refiding in the Eye, in the Pupil. There is ever in my Pupil but the fame Quantity of Light, that always anfwers to the fame Cone of exterior Light, from whence it likewife continually receives (the Light being equal) the fame Quantity of Vibrations, whether the Cone be fmall, that is to fay, fhort, as when I am in my Chamber, or whether it has a great Bafis, or is

long

long, as when I am upon *Montmartre*. All the Difference there is consists in this, that, when I am in my Chamber, my Library, which I have in View, puts the Light in Motion in my Pupil, which all *Paris* would there put in Motion were I on *Montmartre*. Each Volume is, there, instead of a great House, a Palace, or a Church. There would not be more Light in my Pupil on beholding all *Paris*, nor even a greater Motion of the Light that is in it. Only the Parts of Light put in Motion by Books, Pictures, and Tapestry, would be put in Motion by Houses, Castles, and an open Country; that is to say, by Cones of Light corresponding with all these Things. My Pupil, it is true, contains a very small Space of Light to be divided for so great an Extent of Objects. But it is so much the worse in that Respect. For the Extent of Impressions is always the same, and the great Extent of Objects must penetrate the small Extent of my Pupil, and the little Quantity of Light residing there: and if Objects have so great an Extent, or so many Impressions to lodge in this narrow Compass, they will be one upon another, and intirely confused. A House, for instance, will be but a Point of Shade; because it will take up no more Room in my Pupil, than the Point on the Letter i of the Book I read; and from hence arises the Confusion observable in large Prospects. It is therefore evident, that all the Ho-

The EYE.

The EYE.

riſon of *Paris* does not tranſmit more Light to my Eye, than my Chamber when I am in it, or even the ſole Page of a Book, when I look on it near.

Does not this Preciſion of Idea, on the Nature of Images, ſeem to begin to render this Effect ſimple and natural? One cannot, it is evident, be under a Temptation any longer of eſteeming it myſterious, or of making it a Subject of divine Revelation. However, let us conſider it with Attention. Tho' I have done all in my Power to render this a ſimple Phœnomenon, and have ſtripped it of its ſeeming to carry with it ſomething miraculous, there ſtill notwithſtanding remains in it ſufficient Matter to fill us with great Aſtoniſhment and Admiration.

The Light of my whole Chamber, or of a whole Plain, does not come to be confuſed in my Pupil; but the Motions imprinted on the Light that is there already, really croſs one another without any Diſorder, which Motions are ever in prodigious Number. Foraſmuch as each Toiſe of a Plain, containing one hundred Millions of them, correſponds only with a Point in my Pupil, a hundred Millions of Points of Light muſt ſtill be found in my Pupil, a Circle of a Line and a half Diameter. And theſe hundred Millions of Globules are there at their Eaſe. They have Vibrations that croſs one another without the leaſt Moleſtation; that

that is to ſay, the Phœnomenon of Viſion ſuppoſes, that a Circle of a Line and a half, or even a Pin-Hole, contains a hundred Millions of luminous Globules, beſides other Particles of Matter of leſs Subtilty; and farther, that there are between theſe Globules more than a hundred Millions of Pores, or a Space larger than theſe Globules, and theſe other Particles of Matter penetrated by them. In a Word, Viſion ſuppoſes in matter an aſtoniſhing Diviſion, and a Poroſity more than aſtoniſhing; Qualities of Bodies the beſt proved, phyſical Principles the moſt certain. Does not the Microſcope diſcover to us on our Skin five and twenty thouſand Pores in the Space that covers a Grain of Sand? A thouſand of theſe Grains of Sand might find Room in the Pupil, where would of courſe be contained likewiſe five and twenty Millions of theſe Pores. But it ought to be obſerved, that theſe Pores are Orifices of Veſſels made of ſolid Sides, compoſed themſelves of hollow Tubes, and that theſe Veſſels convey to our Atmoſphere a Flood of Vapours. It would be thought a very extravagant Calculation, were I to reckon the Area of this Torrent of Vapours, and the Texture of its Canal at a Million of Particles. One would meet with notwithſtanding five and twenty Millions in a Space no longer than that of the Pupil. That is to ſay, there would be found two hundred and fifty Times a hundred Millions, or two hun-

The EYE.

The prodigious Diviſibility and Poroſity of Matter.

The EYE.

dred forty-nine Times more luminous Globules in our Pupil, than I have counted; and in the mean while what a Difference there is between these gross Particles, and those of Light. Must we not then imagine, that there are not above a hundred Millions of luminous Globules in the Pupil, or at least in a Pin-Hole? I have no Inclination meerly to astonish the Reader; for still even this Number, wonderful as it is, ought to be looked upon as falling far short of the real Fact. Nature does not stop there, and we must follow her. Let us therefore boldly pronounce at once, that there are in the Pupil, not a hundred Millions of luminous Globules, but a hundred Millions of luminous Pencils, composed perhaps themselves of as many Globules, and of abundantly more Pores between them. It is obvious thro' all this Work, that the grosser anatomical Observations lead one on insensibly to these most surprizing and almost incomprehensible Finenesses of Matter.

Admire then these Phœnomena of Nature, not like one devoted to Mysteries, who redoubles his Enthusiasms in Proportion to their Obscurity, and the impenetrable Darkness they are involved in. But be filled with Admiration as a Philosopher, that is touched with the Beauties of the Mechanism which falls under his Conception.

What

The EYE.

What I have been ſaying, concerning the Action of Rays, ſuppoſes that, beſides the Poroſity of Bodies, there is a great deal of Vacuum between the Particles of Matter; and, in my Opinion, there is nothing in Phyſics more certain. I will not pronounce with Sir *Iſaac Newton*, that there is not a cubical Foot of Matter from the Sun down to us. But it ſeems to me evident, that the perfect Plenum is as repugnant to the Laws of Nature, as the compleat Vacuum; and that both the one and the other would render Motion impoſſible: the Plenum by too many Obſtacles, as Sir *Iſaac* has demonſtrated, the Vacuum for Want of contiguous Bodies, without which there can be no Communication of Motion. Beſides, all Matter is porous, and no Matter can be in Contact with another without Vacuities between them. Whatever infinite Series we may ſuppoſe of ſubtile Matter to fill theſe Pores, the Series of Vacuums will be more than infinite, and follow Matter univerſally. How willing ſo ever we may be to unite all theſe Series of Matter without Intervals, if we ſuppoſe them to have a Figure adapted for an exact Conjunction, they would form no more than an univerſal impenetrable Solid. Gold and the Diamond are only Spunges in Compariſon of what would be then the whole Univerſe. One has not, it is objected, the leaſt Idea of a void Space. In the mean Time it was the firſt thing I have

The perfect Plenum of *DesCartes*, and the *Newtonian* compleat Vacuum, are equally impoſſible.

The EYE.

the best Conception of; and I was forced to go thro' a Course of Physicks in order to get rid of this natural Idea, and to be convinced that my Chamber is full of Air. For my Senses had never pointed out to me any thing else than a Vacuum.

As there are Vacuities between the Particles of Light, consequently those Particles are not in immediate Contact, as *Des Cartes* imagined; nor is Light propagated from the Sun to us in an Instant. Because the Vibrations and Undulations of Light run over the small Spaces which divide its Globules, and all Space demands a certain Time to be traversed. Without these Spaces, without these Voids, how can one conceive the Vibrations and Action of Light? But these Spaces are not of that Immensity as those which Sir *Isaac Newton* makes Light run over, and, on that Account, the Propagation of it is more easily conceived.

The

The PRINCIPAL PHOENOMENA of VISION.

Why we ſee Objects ſtrait, tho' they are painted reverſed in the Eyes.

THE Soul muſt ſee the Rays, or rather muſt perceive them in the different Parts of the Eye, in the manner ſhe perceives the Fire that affects different Parts of the Hand. If the Fire burns my Thumb or little Finger, ſhe is under no Miſtake on that Account. In the mean while the Image of Objects conveyed to the Bottom of the Eye is found reverſed from Top to Bottom, from left to right, and yet we ceaſe not to diſcern the Objects ſuch as they are in themſelves. What then in this Caſe becomes of the Juſtneſs of the Soul's Judgment? Or rather by what means will ſhe correct her ordinary Judgment, ſo as not to render it conformable to the Situation of Images and Impreſſions, but intirely ſo to that of Objects? How in ſhort does ſhe convey to the lower Part of the Object, the Senſation ſhe receives at the upper, from the Bottom of the Eye, and to the right the Impreſſion ſhe received from the left?

The

The Sight.

The grand Master the Soul follows in this Particular is the Touch. This sole Sensation is the competent Judge, the sovereign Arbiter of the Situation of Bodies. It is this Master that first told us we walk upright, and that, in consequence of this first Rule, gave us a true Idea of the Situation of other Bodies. The Soul has been convinced by Demonstrations (for such they are) of this Sense, and knows otherwise that the Eyes are very apt to deceive. She therefore said,—Since *Peter*, whom my Hands and the proper Situation of my Body have demonstrated to me to be upright, transmits to the Eye an Image inverted, I will conclude all Objects hereafter to be right, that shall be painted in my Eye reversed, and all those reversed, that shall be painted right. The Judgment of Reason was immediately followed by that of Habitude, and, Habitude once established, it is a kind of Ænigma to divine the manner after which the Soul can see, that is to say, judge Objects right, tho' they are reversed in the Eye.

But why, you will ask, do not those that are born blind, on acquiring their Sight, at first see Objects reversed * ?—These blind have all their

Lives

* It is no where demonstrated, that these Novices in the Art of seeing saw not at first the Objects reversed. On the contrary, we have already proved, that they must have been apprized of this Inversion. But supposing there have occurred some, who have judged Objects upright on the first Use they have made of their Eyes, see how that may be very rationally accounted for.

Lives felt the Objects, and formed an aſſured Judgment of their Situation. Their Soul therefore is not ſo liable to a Miſapprehenſion as thoſe of others are. Nay, it is poſſible the reverſed Senſation may make a Part of the Aſtoniſhment they are ſeized with, on the breaking in of Light; and that in the Crowd of Images, they have no diſtinct Perception of this Singularity. But this Inverſion of Objects has no Effect on their Ideas, ſo well eſtabliſhed by the long Leſſons of their true Maſter, the Touch. The old blind Man, Fig. 3, Plate IX. accuſtomed to conduct himſelf along with his two Sticks, and to judge by means of thoſe of the Situation of Bodies, is not at all deceived in that Reſpect. He knows very well that his Dog, which he touches with his right Stick, is on the left, and that the Tree, touched by his left Stick, is on the right Hand. Should he in an Inſtant be accommodated with two good Eyes, at the Bottom of which the Dog would be on the right, and the Tree on the left, he would ſuſpend his Belief, and refer the Matter to the Demonſtration of his Sticks, which he is convinced are infallible.

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The Soul makes as much of it, at leaſt in regard of all Objects, on which the Experience of the Touch has been able to ſhed its Lights, either immediately, or by Compariſon. I have my Reaſons for adding this Reſtriction. The Principles we have been taking a View of, conducted

The Sight. conducted me to surmize, that the Soul saw sometimes Objects reversed, thro' want of the Means just mentioned. And, in short, I have been happy enough to be convinced of this by an Experiment as singular, as simple; with which one has the additional Advantage of demonstrating the Inversion of Images in the very Eyes of any one that makes the Observation. And here it is.

Place a Light at a moderate Distance from a smooth and very convex Body, in such a manner that a small luminous Point of it may be determined towards yourself. In order to succeed with more Certainty, prevent the first Light from falling on your Eyes. Shut afterwards one Eye, and look at the luminous Point in an indistinct manner, that is to say with the Eye relaxed or dilated. This Point will appear to you larger and beamy. Then if you put your Finger on the right Side of the Eye that is open, and move it towards the Axis of this Eye from right to left in order to cover this luminous Point, you will distinctly find the Shade of your Finger come on the contrary from left to right, and pass over the luminous Point in a Direction opposite to that you gave it. If you afterwards make your Finger pass before the luminous Point from left to right, its Shade will pass there from right to left. In short, if you make it pass from high to low, or from low to high, its Shade will still pass in a contrary

The SIGHT.

contrary Direction over the luminous Point. It is therefore plain, that the Soul fees at firft the Objects inverted in the manner their Images are in the Eye; and that fhe determines the Impreffions to the Places of the Eye, where fhe perceives them, and not to the Places from whence the Rays come, as fhe does when fhe can rectify her Judgment. For here fhe fees my Finger go from left to right, when it goes in reality from right to left. The Soul therefore at that Time concludes the Impreffions reverfed as fhe perceives them, and confequently does not correct her Judgment. And from whence does this proceed? The Reafon of it undoubtedly is, becaufe this luminous Point has neither high, nor low, nor right, nor left, nor any glaring near Object, to awaken and fix the Attention of the Soul. In a Word, there is nothing that can determine her Judgment.

I have farther tried this Experiment on feveral large Bodies moderately enlightened; but this is what ftrikes one moft, and of courfe muft be deemed fufficient.

How we difcern a fingle Object, tho' its Image makes an Impreffion on both Eyes. And why we fee fometimes double.

THIS is another wonderful Phœnomenon, founded on our Ignorance of the manner the Soul is affected in by the Images of Objects. When

The Sight.

When we look upon an Object, each of our Eyes receives an Image of this Object. There are therefore two Images making at one Time an Impression on our Soul, when in the mean while we discern but a single Object.

In case the Soul left one of the Eyes in a State of Inaction, and made use only of one Eye at a Time, or were attentive but to one of the two Images; the Difficulty would soon be solved, which, indeed, is the ordinary Conduct of the Soul. To be convinced of this Point, look with both Eyes, A, B, Fig. 1. Plate X. at the Candle C. Beyond this Candle have two Objects fixed, E, F. Look at the Candle with a strong Attention; and see with which of the two Objects, E or F, corresponds. If with the Object E, it is with the right Eye you discern this Candle. If it corresponds with the Object F, you see it with the left; or at least your Soul is only attentive to the Image painted in one of your Eyes; and this manner of seeing is the most general. We do not observe an Object attentively but with the Eye that is next it, or more within its Reach: while the other Eye is in a Sort of Repose, until its Turn comes to let the other rest. I have myself observed, that there are certain Days, when it is almost ever the Turn of a particular Eye solely to see the Objects that present themselves. And I have had room to conjecture, that this was owing to that Eye's

having

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having on these Days more Vigour than the other. I am perswaded, that, in regard of a Number of People, one Eye is ever stronger or more on the watch, than the other, and constantly takes upon itself the greatest Share of the common Task.

For Instance, *Borelli* asserts, that the left Eye is stronger, and always discerns more distinctly, than the right *. I have verified this Observation by Trials on several Persons: but I have discovered likewise that it is not a general one. There are Eyes perfectly equal, such amongst others are my own. There are, on the contrary, Instances, where the right Eye is the most vigorous. Were *Borelli*'s Observation invariable, and universally true, I would declare without Hesitation, that the right optic Nerve is less supplied with Spirits, and has less Force; by reason that the right Arm, being more active and more employed than any other Part, has a greater Quantity of Spirits flowing thro' its Nerves; and that this great Expence of Spirits is borrowed of the Nerves of the same Side: and that, on this Account, the right optic Nerve, furnishing a good Part of this Contribution, is so much the more impoverished. The same Reason is assignable for the extraordinary Supply of one of the Organs in the male kind subservient to the perpetuating the Species.

Tho'

* Journal des Sçavans, 1673.

The Sight.

Tho' this Sort of one-eyed Vision I have been speaking of, be usual, it is far nevertheless from being universal, as some imagine; and, consequently, cannot resolve the Phœnomenon in Question.

The first Time I was convinced that I saw the same Object with both Eyes at once, I lay in Bed on my left Side, both my Eyes determined vertically, as in Fig. 4. Pl. X. had my Body and Feet extended towards Q; over against me was a Window A; and between me and the Window there was the Back of a Chair B. The Back of this Chair hid from me all the lower Part C D of the Window. I looked at the Window and the Chair in a confused manner, that is to say, as one does ordinarily on waking. I saw all the upper Part A C of this Window, but on the lower, C E, I distinguished a Crowd of Vapours e, e, of the Figure of the Back of the Chair.

On leaving only the right Eye, a, open, I saw this Window A C intirely, without any Part of the Body of Vapours. But, on opening only the left Eye, b, I discerned no more of the Window than the Space A E; that is to say, all that was above the Place where ascended these Vapours.——Consequently, there was only this Portion A E, that was within Reach of being seen with both Eyes at once; the Part E C being hid from the left Eye, b, by the back of the Chair B. It is for this Reason, that, on

looking

looking with both Eyes, I ſaw the Part A E more diſtinct and more luminous, becauſe I ſaw it with both Eyes at once, its Situation being above the Axis, b, e, of the Eye below, and, conſequently, within reach of imprinting its Image on both Eyes. The SIGHT.

The Portion E C appeared leſs diſtinct, or covered with a vapouriſh Column; becauſe this Portion, being ſituated above the Axis, b, e, of the left Eye, b, was hid from this Eye, and ſo was ſeen only by the right Eye, a, which being higher than the left Eye, ſunk its Axis, a, e, above the Chair, to the lower Part, c, c, of the Window. Now this Part E C was ſeen only by one Eye, and, conſequently, affecting but a ſingle Organ, imprinted a leſs Senſation in the Soul. From hence aroſe that feebler Viſion, or the Collection of Vapours, with which the Object appeared covered.

From this Experiment I conclude, firſt, that we ſee Objects with both Eyes at once.

Secondly, that one ſees better with both Eyes than with one. Becauſe the Portion A E, diſcerned by both Eyes, always appeared to me clearer and more luminous.

Thirdly, that one ſees better on looking with Attention, with a Sort of Effort; as one carries a Burthen better on exerting one's ſelf, than when one marches languidly under the Weight.

The SIGHT.

Fourthly, that, in caſe we ſometimes ſee the Object but with one Eye, it is becauſe the Attention is excited rather in this Eye, than in the other, by reaſon that the Object is on the Side of this Eye, and firſt ſtrikes it; or elſe, becauſe we have acquired a particular Habit of putting this Eye on Action rather than the other.

Let us recur to another Experiment of the ſeme kind, which will conduct us a little farther into the Myſteries of Viſion.

Put upon the ſame Line two Candles, C D, Fig. 1. Pl. X. Look with both Eyes AB, and with a ſtrong Attention, on the firſt Candle C, you will find it, as formerly, but one Candle, tho' the Candle C tranſmits an Image to each Eye, A, B. But, if you look at the Candle C, as if you were confuſed, that is to ſay, dividing a little your Attention, between this Senſation and the others your Eyes may receive, then you will ſee at the ſame Time the Candle at a Diſtance D; but you will ſee it confuſedly and double; that is to ſay, one in f, and the other in e, on each Side of the firſt Candle C.

In like manner, if you look earneſtly at the ſecond Candle D, you will ſee it ſingle. But, if you look upon it with a Sort of Diſtraction, you will ſee on its Sides E F, the firſt Candle, C, double and confuſed. It is neceſſary to look at it like one confuſed, to ſee this Duplicity, by reaſon that from the ſtrong Attention,

tion, one fees only with one Eye, or is folely attentive to the Image painted in one of the Eyes, as has been above obferved. The SIGHT.

Let us remark, before we explain this fecond Experiment, that when one looks upon an Object with both Eyes, thefe Organs are turned towards the Object in fuch a manner, that it becomes placed at the Extremity of the Axis of each Eye, and the Centre of each Image is painted on the Choroides of each Eye, at the Point that correfponds with this Axis.

This being fuppofed, it follows from the preceding Experiment, that every Time both the Images fell on the Points of the Choroides, which correfpond with the Axis of each Eye, thefe Images are confounded in a fingle one. But when both Images fall wide of thefe Points, whether inwardly, or outwardly, above or below them, thefe Images are no longer confounded one with the other, but one fees them both, and the Object appears double.

For Example, when you look at the Candle C, you turn both Eyes towards it fo that it is found at the Top of the Angle made by the Union of the Axes of both Eyes, and the Images fall both of them on the vifual Pole, a, a, of each Eye. In this Situation of the Eyes, the Images of the Candle D fall in b, b, outwards, and on this Side of the vifual Pole; and on this Account thefe two Images are

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perceived ſeparately, and the Candle appears double.

For the ſame Reaſon, if you look on the Candle D, while the viſual Pole is b, b, the Images of the firſt Candle C will ſtill be ſeen double; becauſe they fall in a, a, out of the Poles of Viſion: which is the Reaſon why drunken People ſee Objects double. Becauſe their Eyes being half paralytic, as well as their Limbs, are fixed, as it were, and immoveable. They do not direct in an exact manner the viſual Axes towards Objects; ſo that the Images of theſe Objects fall out of the viſual Pole, and, conſequently produce a double Viſion.

An Object is farther rendered double, when, on looking on it with both Eyes, one forces an Eye with a Finger either upwards, or downwards, or ſideways. Hence the Image is diſlodged from the viſual Pole, where it was before, and this Image is ſeen ſeparately.

This ſecond Object, at the ſame Time, ſeems to change Place, and to recede from the former. For, on puſhing the Eye aſide, you make the Rays, which go from the Eye, pointed, A, Fig. 1, fall obliquely on this Eye, and refract themſelves beſides in piercing it. Now, as the Soul ever conveys the Impreſſion of Images in a direct Line, d, h, or to the Extremity of the Axis, d, in Contact with the Organ, or the Bottom of the Eye; it follows, that the ſecond Object ought to appear in h, at a ſufficient

ficient Diſtance from C, which is the real Object. The SIGHT.

The Soul always conveys the Impreſſion of Images in a direct Line, becauſe ſhe does not ſee the Object in the Place where it is. She ſees it in the Eye itſelf: For her Affair is with the Image, not with the Object. Now, from whatever Point the Image comes, after it has pierced the Cornea, the aqueous Humour, and the Cryſtalline, it is refracted for the laſt Time in the vitreous Humour; where it deſcribes a ſtrait Line to the Bottom of the Eye. And it is according to this laſt ſtrait Line lengthened, d, h, the Soul ſees the Object, as if it were on the Eye itſelf. A Perſon, unaccuſtomed to look at Objects thro' a perſpective-Glaſs, would ſee them in the Glaſs itſelf. And I have known, when there has been no perſwading ſome particular People, that the Star I ſhewed them in the Glaſs, was the ſame I made them ſee in the Firmament without it. Any one, arrived at the Uſe of Reaſon the firſt Time of his Life he ſaw, would likewiſe declare the Objects were actually in his Eyes. He would conclude, what we only diſcover by the Force of reaſoning; to wit, that Viſion is a kind of Senſation of the Touch, and would imagine he even felt the Objects on his Eyes. This is what is confirmed by the Hiſtory of one born blind, which we ſhall relate in the Sequel of this Treatiſe. One may be therefore aſſured, that

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Infants see in this manner, and that it is in us an Art, a Science, acquired by a Habit of judging that Objects are external in our Regard, and at a certain Distance.

I was saying, that an Object discerned with both Eyes appeared single, when each Image falls directly on the Point of the visual Axis, or on the Pole of each Eye; and that appears double, every Time the Image falls wide of these Points.

Let us make some farther Experiments, before we examine what this Point of the Axis, this optic Pole, is.

Place two Candles, E, F, Fig. 2, Pl. X. at a certain Distance one from the other. You are in C. Look at these Candles thro' a Hole, o, made in a Board, or a Pasteboard A, B, and you will see both Candles, but you will see two Holes, one for each Candle, tho' there be but one Hole for both. The Reason of it is, because when you look at both Candles E, F, the Axes of both Eyes a, G, a, are directed to the Height G, which is the common Point in this Distance. In this Direction of the Eye, the Image of the Hole, o, falls obliquely, o, b, on each Eye, and out of the optic Pole. Therefore the Hole must appear double, and each Hole has its Candle, because the Candle, E, falls just by the Hole, o, upon the right Eye in E, and likewise out of the optic Pole; the Candle F falls by the same Hole, o, on the left

The SIGHT.

left Eye, ſtill in b, out of the optic Axis. There is only the Point G which falls upon the Axis, a, a; and as the Soul reports the Situation of Objects according to this Axis, the two ſeeming Holes, with their Candles, appear in f, g, on the Side of the true Hole.

In the mean while, if you look earneſtly at the real Hole, o, the Line b, o, becomes the optic Axis; ſo that you will ſee only one Hole and one Candle, tho' there be two Candles. You will ſee but one Hole, becauſe it is at the Top, o, of the Optic Cone, b, o, b. You will ſee but one Candle made of both, becauſe both Images are actually confounded at this Top of the optic Cone in paſſing by the Hole, o, and fall as well as the Hole upon the viſual Axis, o, a. Now Objects, it is to be remembered, whoſe Images fall in this Axis, always appear ſingle, altho' they have an Image in each Eye.

It is true, that the ſingle Candle which you ſee on looking ſtedfaſtly on the Hole, is compoſed of both: and that if you put your Hand before one of the two Candles, you ſee that which is before your Hand, and ſee beſides the Tranſparency which that, which is behind, produces acroſs your Fingers. Or elſe, if you put a yellow Glaſs before one of the Candles, and a blue Glaſs before the other, the ſingle Candle which you ſee will be green; that is to ſay,

The Sight.

compofed of the yellow of the firft Candle, and the blue of the fecond.

Inftead of looking thro' the Board, A, B, place at the Hole of it the pierced Pafteboard, x. Look thro' this new Hole at both Candles, E, F, you will fee two Candles and two Holes as in the preceding Experiment. But, on looking earneftly at this Hole, o, of the Pafteboard, inftead of feeing only a fingle Candle, you will fee three of them; to wit, the Candle compofed of the two that pafs thro' the Hole, o, as in the firft Experiment, and moreover the Images a little confufed of each Candle E, F, that will pafs on the fide of the Pafteboard by the Lines F, K, and E, K; Images that were before intercepted by the Board A, B.

If you examine the Eyes of whoever makes the preceding Experiments, you will obferve that when he looks earneftly at the Hole, o, his Eyes are approached one to the other according to the Angle b, o, b; and that when he looks at the Candles E, F, tho' thro' the fame Hole, his Eyes, or rather his Pupils, are vifibly wide of each other, and placed in the Directions of the Angle a, G, a. So that the Explication is verified even by ocular Infpection.

If inftead of looking with both Eyes, one looks only with one, then this Eye does not change the Direction, whether one looks at the Hole, or at one of the Candles; fo that one never

never fees more than one Hole and one Candle. Confequently, the Phœnomena I have been obferving depend on this; that, on looking with both Eyes, each Eye affifts, by reafon its Direction concurs in the common Axis, C, G: for Example, the right Eye fingly would be directed in b, E, the left Eye fingly in b, F. But when they fee together, their Direction takes a common Medium G, and from thence proceed the foregoing Miftakes. The SIGHT.

To omit nothing, farther defirable, in regard of thefe Phœnomena, it is neceffary to determine the optic Poles, thofe Points of the common Axis, where Objects appear fingle, and out of which they appear double, and to affign the Reafons for thefe Appearances.

The optic Axis was heretofore imagined to be the Center of the optic Nerve. Thefe two Nerves were faid to crofs one another, and on that Score the Impreffions which fell on both thefe Nerves, being conveyed along their Tubes, were fuppofed to meet in a fingle Point at the croffing of thefe Tubes, and to be there confounded together.

We have feen above, that the Centre of the optic Nerve is incapable of this Function. But, tho' it were capable of it, this croffing is imaginary.

Some of the Moderns, apprifed of thefe Difficulties, have fixed the optic Axis on the Point x, Fig. 4. Pl. X. of the Choroides, or of the

pia

The SIGHT.

pia Mater, which is on the inner Border of the Insertion of the optic Nerve; and say, that these Portions of the *pia Mater*, uniting before the Concourse, y, of the two optic Nerves, exactly where the common Axis, y, t, corresponds, both Impressions must necessarily be resolved into one.

These Gentlemen do not succeed a Jot more happily than the former. First, it is a Fact proved by the most exact Anatomy of the Eye, and by the Experiment of M. *Mariotte*, see p. 154, *&c.* that the Axis of the Globe of the Eye, or visual Axis, falls on the Outside of the optic Nerve, as it is represented in all our Figures. Secondly, the Sensation is made in the Organ itself that is affected. The Prick of a Pin upon the Finger affects the Finger. A Ragout that one tastes, affects the Tongue; and, consequently, Light affects the Eye, and not the Origin of its Nerves, as we have seen in the general System of Sensations. Thirdly, by supposing but one Point in the Bottom of each Eye, where the Impressions are united; would this simple Point suffice to give us a single Image of an intire Country that fills the whole Bottom of our Eye? By admitting a Point of this Nature, there would in like manner be but one Point of this Country, where we should see single Objects, all the rest of the Country would be double, by reason it would not fall on this Point.

The

The optic Pole is not a Point. What is it then? It is the whole Bottom of the Eye that has the optic Axis for its Center. Now every Image, whoſe Center correſponds with that of this Pole, repreſents to us a ſingle Object, altho' the Image be in each Eye; for the ſame Reaſon that we hear, with both Ears, a ſingle Sound, tho' it makes a double Impreſſion. It is not becauſe the Senſations are confounded by the Re-union of the Motion; which is a Chimera, and really found to be ſuch, in both thoſe Ears, whoſe Nerves and Organs are very different. It is the Mind herſelf that makes this Re-union by a Judgment ſhe acquires by Habit and Experience. She knows that a ſingle Object is that which occupies one Place only proportioned to its Circumference; and that a double Object is what occupies a double Space, or is in two different Places. So that when there arrives an Image in each Eye, both which Images are carried in a ſtrait Line to the ſame Point, the ſame Place, and are preciſely the ſame in their Poſition and Form, inaſmuch as the Object is in the Axis common to both Eyes, and occupies the ſame Place, the ſame optic Pole, and affects the ſame Parts in each Eye; then it is the ſame Senſation proceeding from the ſame Quarter; ſo that we conſider this double Image as a ſingle Object: for we perceive and ſee but one Object.

If

The SIGHT.

If an Eye is turned out of the common Axis, the Direction of the Image is changed, and the Object appears double, as we ſee Plate X. Fig. 1. at the Eye that is pointed; becauſe, in that Caſe, you fancy this Image in a different Place, h, to that C, from whence the Image arrives, and from whence it is received by the other Eye, B. Now each Image being carried to two different Places, C, h, we imagine the Object double, becauſe it appears to occupy two Places.

How ſquint-eyed Perſons ſee.

One that is ſquint-eyed, however, looks at Objects with both Eyes tranſverſely, without ſeeing them double. It is true. But a ſquint-eyed Perſon, without being conſcious of it, ever ſees but with one Eye, tho' he imagines he looks with both. I lately unfolded this Doctrine to one that ſquinted very much with his left Eye, who at the ſame Time firmly believed he ſaw with both Eyes at once. I aſſured him that he only ſaw with his right Eye, and it was thus I convinced him.

I made him look with both Eyes, A, B, Pl. X. Fig. 3. at the Object C. I obſerved his Eyes while he looked at the Object; and the better to diſtinguiſh the Direction of them, I had likewiſe remarked thoſe of a Perſon whoſe Eyes were right. I ſaw then that the ſound right Eye, B, of the ſquinting Perſon, was actually turned towards the Object; but that

that the other Eye A, at the ſame Time was turned towards D. The SIGHT.

It may be objected, that it was perhaps in this Direction A, D, that the ſquinting Eye ſaw the Object, C. But in order to obviate this, I put my Finger at D, where the left Eye was directed, when the Perſon ſaid he looked with both Eyes at the Object C; and the Inſtant he looked thus at the Object C, I ſhut his ſound Eye, and begged him to look at my Finger, D, with his ſquinting Eye, A. He looked, and ſaw my Finger without the ſquinting Eye's changing the Direction A, D, which it had when he ſaid he looked with both Eyes at the Object C. I deſired him afterwards to look on the Object C with the left Eye; and then this ſquinting Eye, looking ſingly, was turned towards the Object C, as exactly as the ſound Eye B had done before: From whence it follows,

Firſt, that the optic or viſual Pole of a ſquinting Eye, is the ſame as that of a ſtrait Eye: ſince, when it acts ſolely, and really ſees an Object, it turns its Axis upon this Object, as the ſtraiteſt Eyes do.

Secondly, that when one who ſquints, views an Object with both Eyes, he ſees it, in the mean while, only with the ſound Eye: inaſmuch as the other is directed every where but on the Object; and, as it is evident by the foregoing Propoſition, that, on looking at an Object,

The Sight. Object, he directs his Axis towards this Object. It is no astonishing Circumstance, that a squinting Person sees but with one Eye; since, as we have proved above, generally speaking, those that have Eyes the straitest and best directed towards Objects, see them, notwithstanding, but with one Eye: because ordinarily the Imagination attends only to that of the two Images, which makes the stronger Impression, and therefore sees solely with the Eye that is strongest and quickest. Now a squinting Eye is vitiated, feeble, unactive, and consequently is ever idle when the other is on Duty. But when the sound Eye is shut, then all the Spirits, all the Efforts of Attention, are determined to the squinting Eye. These Efforts put it in an Equilibrium on its Axis, direct it towards Objects, and then the Eye no longer squints, but sees. It is by this Management, that the Eyes of Children are sometimes cured, by closing their sound Eye, and forcing by that means the squinting one to rectify itself. We have seen here a famous Quack * abuse this Mechanism, in order to impose upon the Public, and even the most intelligent Part of them.

In making the Experiments I have been mentioning, a Person was found out, who had the Knack of mimicking one that squinted. But this voluntary Squinter saw Objects double, because

* Taylor.

because his Eye, tho' turned from the common Axis was ſound, and active, and no Ways impaired, thro' Inactivity and Want of Uſe: ſo his Caſe was like that of thoſe, who puſh an Eye aſide with their Finger.

The SIGHT.

It is by this ſame Explication we account for the following Obſervation. A Perſon became ſquint-eyed from a ſudden Accident, and at firſt ſaw Objects double. But in Proceſs of Time, tho' his Squinting continued, he ſaw them ſingle, as before he grew ſquint-eyed. It ſeems to me evident, that this ſquinting Eye was, in the Beginning, ſtill ſound, vigorous, and in the State of the Eye of our voluntary Squinter, which was the Reaſon why he ſaw double. But at length this Eye, either thro' the Illneſs that had occaſioned this Defect, or thro' Inactivity, loſt by Degrees the Faculty of ſeeing, which now depended wholly upon the good Eye, and then the Perſon began to ſee Objects ſingle.

In the mean while, in caſe there be a Squinter in the World, that ſees an Object with both Eyes at once without ſeeing it double, the optic Pole of his ſquinting Eye muſt have never been in the Axis of the Globe of the Eye, whether thro' a Defect in its Conſtruction, or thro' Habit, if Habit can even here avail any thing; or elſe this Eye, from the Refraction made in it being different from the ordinary one, muſt have been obliged to throw itſelf towards

The Sight. wards one particular Side, in order to make the Image fall upon the optic Axis, which afterwards grew into a Habit. Refraction in an Eye may be likewise disconcerted thro' the displacing of the Crystalline Humour, the irregular Formation of the Eye itself, *&c.*

But both in one and the other Circumstance, should such squinting Persons look at an Object, the good Eye being shut, the other would not at all rectify itself, as it does in all other Cases. It would look a-squint being single, as if it were with its Fellow: since, in the first case, the optic Axis is supposed to be a-skew, and in the other, where Refraction is disconcerted, the Image can no ways fall upon the optic Axis, tho' strait; nor is the Eye turned a-slant to catch the Point, where this disconcerted Refraction conveys the Image upon the optic Axis.

From all this we conclude, that the *optic Pole* is that Region of the Bottom of each Eye which is in Sympathy with the other, and whose Center, called the *optic Axis*, ordinarily the Axis of the Globe itself, is directed to and uninited with the common Axis, when both Eyes actually look at an Object; that every Time this Union is made, the Image of the Object, tho' double, one in each Eye, causes us to see but a single Object, because both Images are conveyed to one and the same Place; and that out of this common Axis the Object appears double,

double, because each Axis of the Eye, and consequently each Image, is tranſmitted to Places different one from the other, and that thus the Image of the ſame Object correſponds with two different Places.

The SIGHT.

How we judge by the SIGHT, *of the* Magnitude *and* Diſtance *of* OBJECTS.

EFFECTS *of* Glaſſes, *and* poliſhed Surfaces, plane, convex, *and* concave.

THE Mind not only rectifies the Image of Objects which occurs reverſed in the Bottom of the Eye; it not only ſimplifies the double Impreſſion of theſe Images in a ſole and ſingle Senſation; but judges, moreover, of the Diſtance and Magnitude of the Objects it diſcerns. What means does it make ſubſervient to this third Operation?

The firſt of theſe means is the Magnitude of the Image itſelf, tranſmitted to the Bottom of the Eye; or, as we ſay, the Magnitude of the *viſual Angle*. There can be nothing more ſimple and more natural, than this firſt Expedient by which the Mind judges of the Magnitude of an Object, by the Magnitude of its identical Image.

First Rule is the Magnitude of the Image itſelf in the Bottom of the Eye.

We have ſeen that the Rays croſs one another at their Entrance into the Eye. Now the nearer the Object, from whence theſe Rays are tranſmitted, is to the Eye, the more conſiderable

The nearer the Object, the larger is the Image, in Proportion.

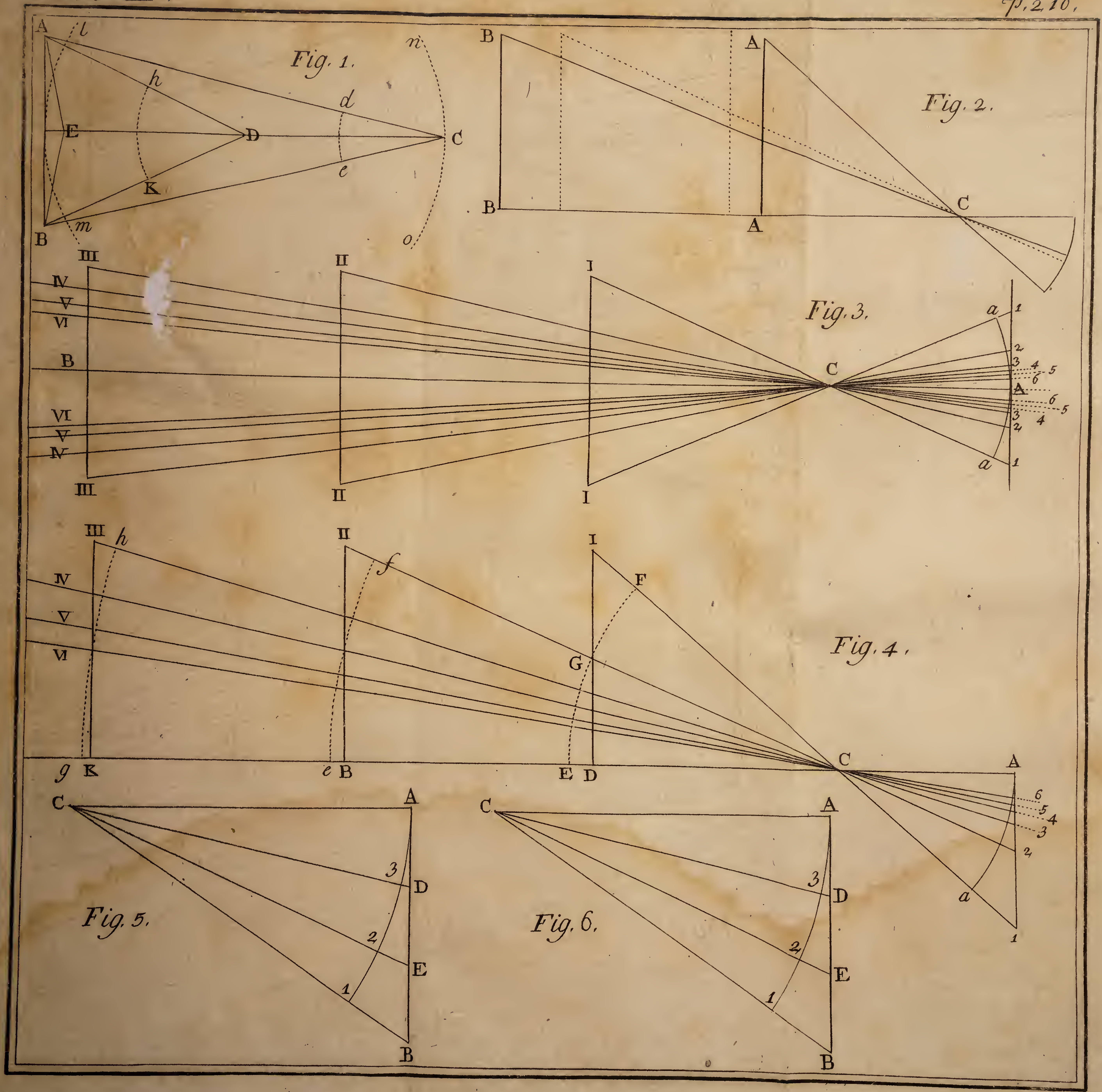
The Sight.

able is the Angle formed by this crossing. For Example, if one looks at two small Statues of the same Magnitude, 1, 6, Pl. XII. Fig. 1. one at the Distance of a Foot, the other of six Feet; the Statue placed at a Foot's Distance will appear to us almost six Times larger than the Statue placed at the Distance of six Feet: because the Opening b c of the visual Angle of the first Statue, 1, or the Height of its Image, is near six times as large again as the Opening e f of the visual Angle of the second Statue, 6. It is upon this Principle that all Perspective is founded.

An Object viewed near, forms in the Eye a larger Angle, because the Base of an optic Triangle, which is the Object itself, being nigher the Eye, the Triangle becomes shorter, and so the Angle on the Top is rendered so much the larger. If the Object A, B, Pl. XI. Fig. 1. is seen from the distant Point C, the optic Triangle is A C B. If you view it afterwards near, as from D, you have then for the optic Triangle A D B comprised in the former Triangle, and obtaining the same Base as that. Now the smaller or shorter is the contained Triangle, so much larger will its Angle D be in Proportion, than the Angle C *. So far, that if the contained Triangle is extremely short, as AEB, the Angle E will be so obtuse, or so large, that both its Sides A E, B E, will form almost

* Euclid, B. I. Prop. 21.

Plate. XI. p. 210.



almoſt a ſtrait Line; and in caſe one conceives the Triangle infinitely ſhorter, the Difference of the Angle E, with the ſtrait Line AB, will be infinitely ſmall. Therefore the nearer the Object is, which we ſurvey, the larger muſt be its optic Angle. The Triangle, we have been ſpeaking of, is the optic Triangle ſituated between the Object and the Pupil, or, it is the outer optic Triangle. By the croſſing of the Rays in the Pupil, there is formed in the Eye a Triangle proportioned to the former. It has its Baſe at the Bottom of the Eye, and its Top oppoſite to the Top of the exterior Triangle. Conſequently, theſe Angles of the Tops are equal, and the Sides of each Triangle are proportional, and the Baſes themſelves are in Proportion. The larger the top Angles are, the larger theſe are.

The SIGHT.

But why does not an Object at twice the Diſtance, form an Image as ſmall again, and an Object ſix times as far off, an Image ſix times ſmaller? The Reaſon is, becauſe it is demonſtrative by Geometry, that the great Angle D, which is as near again to the Baſe A B, as the ſmall Angle C, is not in the mean while as large again as this ſmall Angle C, but falls ſomewhat ſhort of it. For the Arch h K, double the Arch d, e, the Meaſure of the Angle C, is larger than is requiſite to meaſure the Angle D. There is a ſmall Overplus; and ſuppoſing there had been none at all, and that

The Magnitude of the Image not exactly proportioned to the Diſtance of the Object from the Eye, but wants a little of it.

The Sight.

the Angle A D B were exactly double the Angle ACB, the Sides of these Angles must have terminated in the Points l, m; because in that case both those Angles would be comprised in the same Circle; the more acute Angle C would be in the Circumference of this Circle, the less acute Angle D would be in the Center of the same Circle, and both of them would have for a Base the same Arch, l, m, of the Circle, Portions of which are exhibited in the Figure at l, m, n, o. From whence it follows in Geometry, that this latter Angle D would be double the other Angle C *. But as the Angle D is not wide enough to fall in with the Sides of the Angle C at the Points l, m, it follows that it is not large enough to be double the Angle C. Consequently, the Image seen as near again (D) will not be intirely as large again; and for the same Reason the Image seen at twice the Distance C will not be exactly as small again, according to these Geometrical Laws.

Let us examine these Proportions in another Point of View more immediately connected with the Matter in Hand. The real Magnitude of Objects is ordinarily an upright Line and perpendicular to the Horizon, I, D, Fig. 4; whereas the Measure, and consequently the Magnitude of the optic Angle is the Arch, or the Curve E, F. Now Geometricians demonstrate, that this Curve E F is less than the upright

* Euclid, B. III. Prop. 20.

right Line I D; and that thus the apparent Magnitude of Objects, or their Image, is leſs than their real. They demonſtrate farther, that this Curve E F, which is leſs than the upright Line ID, is alſo in a leſs Ratio with its Diſtance D C, than e f is with the Diſtance B C; that is to ſay, the Curve or the Image E F of the neighbouring Object is not ſo large, in regard of the Diſtance D C, as the Curve or the Image, e f, of the diſtant Object, is in reſpect of its Diſtance B C. For it is evident, that the nearer the ſame Object is to us, the wider is the Angle, and the ſhorter the Arch E F formed at the Center C; and the more it contracts, likewiſe, the Baſe of the optic Angle, and the Image this Baſe tranſmits. The ſole Inſpection of the Figure may convince any one, that the Arch f e, which is at the ſecond Diſtance, is leſs curved than the Arch E F; and that it diminiſhes ſo much the leſs of the real Magnitude of the Object; and that the Arch g h, which is at the third Diſtance, does ſo ſtill leſs than e f, and ſo on. On which Account the nearer an Object is, the more its Image ſuffers from this Sort of Abatement, which hinders the Magnitude of this Image from correſponding exactly with the Proximity of the Object.

The SIGHT.

The Rays croſs one another in the Eye, as at the Point C, and there form Angles almoſt equal to the exterior Angles. I ſay almoſt, be-

The Sight.

cause Refraction in assembling the Rays, still straitens, in a small Degree, the Base of these inner Angles. The Eye is spherical. Therefore the interior optic Angle is measured and bounded by a Curve A a, which reduces the Images, as well as, it is evident, the exterior Angles are. This inner Curve is the essential one. It is that which measures the Extent of the Impression, and gives the Form and the Magnitude to the Image. It is this Curve that cuts off the Portions k b, h c, of the large Image b c of the Statue i, Fig. 1. Pl. XII. and retrenches nothing or scarce any thing of the small Image, e f, of the Statue 6. It is this same Curve of the Eye, that so much abridges the large Angles of the Figures 3, 4, Pl. XI. and hinders besides their Images from being proportioned to the Proximity of Objects; whilst it shortens very little, or nothing at all, the strait Angles, or the Angles of distant Objects, and on that Score causes a less Diminution of their Images, than of those of nearer Objects. From whence the Images of distant Objects are larger, considering their Distance, than the Images of neighbouring Objects are in regard of their Proximity.

One will remark therefore in these Figures, on measuring the optic Angles, by the Curve which describes the Bottom of the Eye, that the Object. II. Fig. 4. that is but as far again as the Object I. transmits to the Eye an Image

A 2,

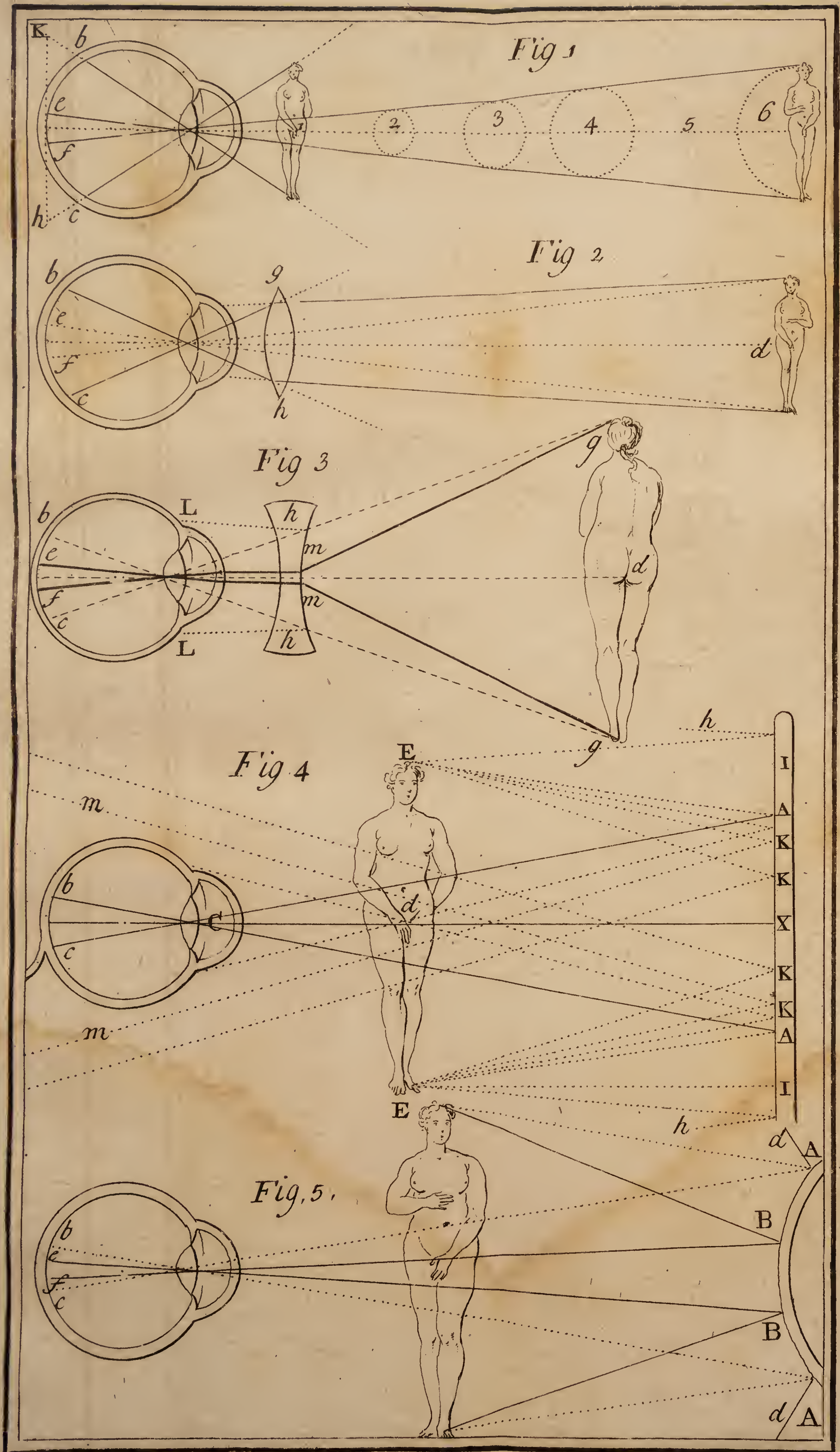


Fig 1
Fig 2
Fig 3
Fig 4
Fig. 5.

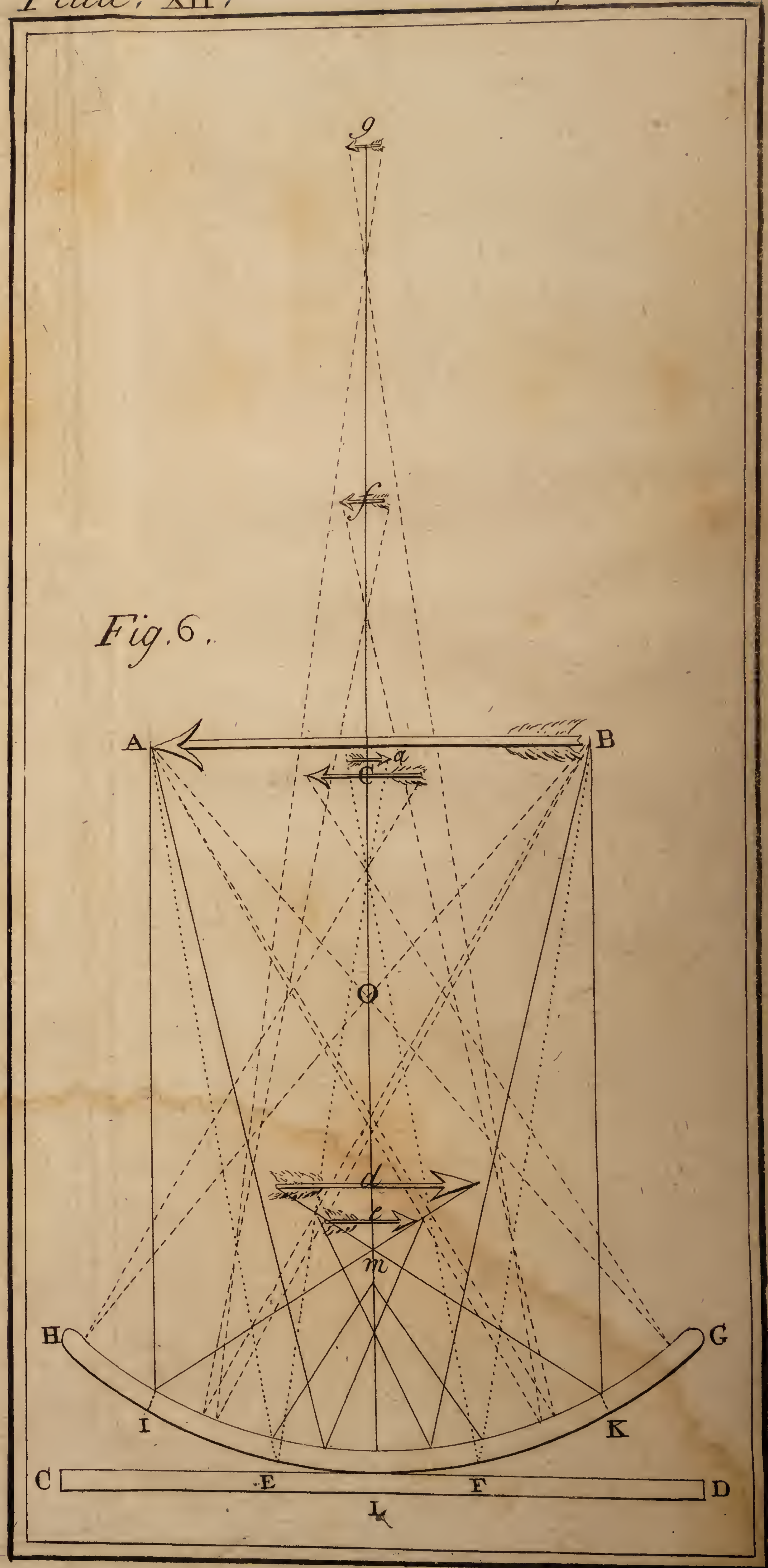


Fig. 6.

A 2, which is more than the Moiety of A a. It will be alſo obſervable, that A 3 is more than a Tierce of A a, and ſo of the reſt; and that conſequently the Object A, Fig. 2, which appears as large again as the other Object B, of equal Magnitude, muſt be a little more than as near again as that other Object B. Or, which is the ſame Thing, this other Object B, muſt be at twice the Diſtance as the Object A.

The SIGHT.

Why it is difficult to judge of the Magnitude of very remote Objects.

It is ſtill farther evident, that the Openings of the Angles A 3, A 4, A 5, and A 6, Fig. 4, are ſo much the leſs ſeparated one from the other, as the Angles are more acute, or come from a greater Diſtance. The farther one goes in counting 1, 2, 3, 4, 5, 6, the nearer are theſe Angles, and the leſs Difference there is between them. In the mean while, if one conceives the Train of Objects carried on to a much greater Length, or even to an Infinity, this infinite Series of Objects ranged upon A K will have no more than the Opening of the Angle A 6 to partake of. So that there will be in this Opening of the Angle an infinite Series of Images all differing in Magnitude. Therefore their Difference will be infinitely ſmall. Hence it is, that at a great Diſtance, ſcarce a hundred Toiſes of Separation between two Objects will cauſe ſome Difference in regard of the Magnitude of their Images; which is the Reaſon why our Judgment on the Magnitude of very remote Objects is ſo uncertain.

The Sight.

The third Figure exhibits the same Thing, by supposing the visual Axis perpendicular to the middle of the Objects, or the optic Isosceles Triangle.

It is also visible in the Figures 3, 4, that without this Curve, which measures and bounds the optic Cone, the Rays carried on to the upright Line A 1, parallel to the Objects I, II, III, *&c.* would form Images whose Magnitude would be exactly in a reciprocal Ratio of the Distances, that is to say, as large again, when the Objects should be as near again, *&c.*

For we learn from Geometry, that in a rectangular Triangle, Fig. 5. if the Angle C be divided into several equal Parts, 1, 2, 3, the opposite Side A B will be divided into several unequal Parts A D, D E, E B, of which those will be the largest, that shall be the most remote from the right Angle A. Because the farther the Side A B is extended from the right Angle A, the wider it keeps from the Arch A 1; the larger Spaces the dividing Rays, 1, 2, 3, run over, in order to reach the Side AB, and the greater Distances they leave between them.

On the other Hand, if one divides the Angle C, Fig. 6. or the Arch A, into Parts unequal and proportional to the unequal Parts of the Side AB of Figure 5, but in a reversed Order; to wit, the greater Part being placed near the right Angle A, Fig. 6. and the smaller Part the

farthest

farthest from this Angle, the Side AB will be divided into two equal Parts: that is to say, the same Obliquity, or the same Departure from the Tangent A B, in relation to the Arch A 1, which, as in Figure 5, has transformed upon the Tangent, the equal Division of the Arch into a Division unequal, and ever the larger the remoter it is from the right Angle; this Departure, I say, operating upon these Inequalities disposed in a contrary Direction, must reciprocally efface or destroy these same Inequalities which it has produced, and restore upon the Tangent AB the Equality given in the former Problem. Because here the smaller Part becomes placed overagainst the greater Departure, and receives on that Account the greater Addition; while the larger Part is placed near the right Angle, and so receives the less Addition. In short, this second Operation is only the first reversed. Therefore it must restore the former given Magnitudes, or equal Parts, as, in Arithmetic, Addition and Multiplication restore the Numbers that were sunk by Subtraction and Division.

Now the Triangle of Fig. 6. resembles exactly the inner optic Triangle of Fig. 4. and the two rectangular Triangles, in which one may include the Isosceles Triangle of Fig. 3. by looking on its Axis, or its Height, B C A, as the Side common to both Triangles. In these rectangular optic Triangles, all the Angles are likewise

The Sight.

wise unequal, and by so much the larger, in respect of their Distance, as they are nearer the right Angle. Wherefore these Angles, lengthened even on a plain Base, must also lose their Inequalities, and, consequently, be perfectly in a reciprocal Ratio of the Distance of Objects. However, I voluntarily resign these profound and more or less abstruse Points to greater Geometricians. As to my own Geometry, take the following Specimen of it.

Decisive Experiments on the Magnitude of Images at different Distances.

I procured some human Eyes and some Eyes of Animals, and stripped their Bottom of the Sclerotis, and the Choroides, when they came from young Subjects. I let the Choroides remain on those that had belonged to old People, because in their Eyes the Choroides has lost its black, and is sufficiently transparent. I disposed equal Objects at unequal Distances, as at one Foot, two Feet, three Feet from the Eye destined to receive the Images. I placed a Wax-Candle-Light at each End of the Objects, in order more distinctly from its Clearness to ascertain the respective Bounds. I afterwards measured the Spaces these three Objects took up in the Bottom of the Eye, and found that their Spaces were exactly enough proportioned to their Proximity; that the Object at the Distance of one Foot was thrice as large as that placed three Feet off, and as big again as what was at two Feet's Distance, measuring with a Compass.

The

The Bottom of an Eye laid open does not easily preserve its regular Figure. The Eye of a dead Person is not always full, and the Membranes and the Humours take all Sorts of Forms between the Fingers. These Defects are partly rectified by supporting the Bottom of the Eye with a transparent Paper. But the Bottom, by this means, becomes flatted, and the Figure of it approaches to the strait Line A 1. Fig. 4.

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Then the most open Angles are no longer cut off by the Curve A, a; and it is undoubtedly for this Reason, that the Magnitude of Images appears proportioned to their Proximity, as much as one can discover by a mechanical Operation. But it is to be supposed, that in a living Eye these Defects no ways occur, and that this Organ being exactly enough spherical, the Images of neighbouring Objects suffer in it the small Diminution demonstrated by Geometry in the Triangles measured by an Arch.

To remedy the Inconveniencies arising from the Softness and Variableness we have been observing in these Eyes, I ordered an artificial Eye to be made of more than four Inches Diameter, furnished with a Glass Cornea and Crystalline Humour, or with the Lens of a Focus proportioned to this Diameter. The Bottom of this Eye was extended on a transparent Paper perfectly plain, by reason of the Difficulty of making a Bottom of this Paper regularly convex. I exposed this Eye to the preceding Objects, and

The SIGHT. and farther found that the Magnitude of Images was exactly in a reciprocal Ratio of the Diſtance of Objects, as ſmall again, when the Objects were as remote again, *&c.*

In order to render the Differences of Images more perceptible, and leſs expoſed to inevitable Errors in the mechanical Meaſures, I augmented the Diſtances, and made uſe only of two Objects. I placed the near Object at a Foot's Diſtance, and the remote Object at that of ten Feet from the Eye. The Image of the near Object took up, on the Bottom of this Eye, the Space of three Inches, four Lines, and a half, of Diameter; that of the remote Object had more than four Lines, and this laſt Magnitude, carried ten Times with the Compaſs over that of the neighbouring Object, meaſured it exactly. In a Word, the Image of the Object at ten Feet Diſtance was juſt a tenth Part of the Image of the Object at that of one Foot. I have repeated this Experiment twenty Times without finding the leaſt Variation. The ſtrait Figure of the Plain, that receives theſe Images, is undoubtedly the Cauſe of this Proportion, for the Reaſons aſſigned above. It is alſo poſſible, that Refraction which acts more forcibly on the Rays of remote Objects, has ſome ſmall Share in it. However that be, it will always follow, that, from the ſpherical Figure of the Eye, there never can occur any conſiderable Alteration in this Proportion. Theſe are inconteſtable

teſtable Facts, and of Courſe ſuch as both Phyſics and Geometry itſelf muſt ſubmit to. The SIGHT.

Not only Perſpective is founded on the Principles we have been expounding in relation to the Magnitude of the optic Angles, and the Images they convey; but it is on thoſe likewiſe depends all the Mechaniſm of Teleſcopes and Microſcopes, of Glaſſes and poliſhed Surfaces, which either enlarge or diminiſh Objects.

Effects of a Convex Glaſs.

When one looks at the Object d, Fig. 2. Pl. XII. with the naked Eye, the Cone of Light which this Object tranſmits to the Eye forms the Opening of the Angle, e, f, as in Fig. 1. and we ſee this Object in its natural Magnitude, with reſpect to its Diſtance. If we then place a lenticular Glaſs before our Eye g, h, this convex Glaſs collects the collateral Rays g, h, which without that would not enter the Pupil. Hence the Eye is penetrated with a luminous Cone of greater Dimenſion, and with a larger Image than what would naturally preſent itſelf. It refracts beſides all the oblique Rays in determining them to the Perpendicular, and, conſequently, in making them croſs in a wider Angle. By that Means it transforms the viſual Angle, e, f, into the Angle b, c, from whence reſults an Image of the Object, d, a great deal larger than the former. Thus the Imagination, deceived by its ſureſt Rule, looks upon this Object as of a greater Extenſion than it was before.

All

The SIGHT. Effects of a concave Glass.

All this will be intirely reversed, in case we place before our Eye a concave Glass, h, h, Fig. 3. Pl. XII. The great Statue, g, g, independently of this Glass, would form in our Eye the large Angle, or the large Image, b, c. But when the first Rays, g h, g h, present themselves to the concave Glass, they are turned from the Perpendicular and from the Axis of the Eye, and approach to fall very wide of the Pupil in L, L. The subsequent Rays do the same, even to the Rays, m, m, which being very near the Axis are the only ones that can fall on the Pupil in spite of the Refraction. These Rays, m, m, are therefore those alone, that can convey to the Eye the Image of the Statue: but these Rays can form in the Bottom of the Eye but a very acute Angle, but a very small Image, e, f. The great Statue, seen through the concave Glass, h, h, will appear of course very small.

These Accounts of the Effects of convex and concave Glasses might satisfy a simple Naturalist. But a Naturalist, that is versed at the same Time in Anatomy, must farther see these different Determinations of the Rays upon the Parts themselves in the Bottom of the Eyes. I therefore took some Eyes stripped to their Bottom, as in the preceding Experiments, and, after having made some illumined Objects fall upon them and remarked their Angles, I placed before these Eyes convex Glasses, and saw the Angles

Angles enlarge themſelves in proportion to the Convexity of the Glaſſes. I afterwards made uſe of ſome that were concave, and found theſe ſame Angles diminiſh in the ſame Proportion.

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What a concave Glaſs effects by Refraction, a convex poliſhed Surface does alſo by Reflexion. But we ſhall not proceed to the convex Surface, without having firſt explained the more ſimple Phœnomena of the plain Surface, and ſaid a Word or two concerning the Nature of Mirrors, or of Surfaces, that reflect, in the moſt lively manner, the Images of Objects.

The Nature and Effects of Looking-Glaſſes.

A Mirror is made either with a poliſhed Body, ſuch as Steel, that immediately reflects Images, or with a poliſhed and tranſparent Body, as Glaſs is, behind which is applied a Matter endued with a Property of reflecting Light; which is generally a Plate of Tin. This Plate is laid upon a very ſmooth Stone, and covered all over with a Bed of the pureſt Quickſilver. If one has the Curioſity to behold ones ſelf in this Bed of Quickſilver, it would appear, that there is no ſmooth Surface in Nature, which tranſmits an Image ſo exact and diſtinct. The Glaſs is then placed upon this Bed of Mercury, and loaded with a good deal of Weight to preſs out what is ſuperfluous, and leave only that which is neceſſary to fill the Pores of the Surface of the Glaſs, and of the Plate of Tin, and thus to faſten both Surfaces together. This Compoſition is afterwards placed in a ſloping Direction,

The Sight. Direction, and then in an upright one, in order to drain the supernumerary Quicksilver, and then the Glass is tinned over. Now it is this Plate of Tin, impregnated with Quicksilver, and fastened by it to the Glass, that reflects the Images, or at least the most lively of them. For in a thick Glass, on holding it in a particular manner, we discern two Images, one reflected by the Tin, the other by the Surface of the Glass. This latter Reflection is a very faint one, and requires some Art to discover it. The Light, on the contrary, reflected by the Tin, is strong and lively, and ordinarily effaces the former. In the mean while, if one has a mind to see distinctly this feeble Light reflected by the Surface of the Glass, all one has to do, is to place behind a Glass, that is not tinned, some black Substance to absorb the strong Light which effaces the other; such as black Velvet, black Paper, or a Hat. We see ourselves but faintly in this second Kind of Mirror, because the Image is formed only of the Light reflected by the Surface of the Glass, which Light is ever weak in comparison of that which pierces the Glass, and is reflected by the Plate of Tin.

In order to expound the Effects of a plain Mirror, let us suppose the large Statue, Fig. 4. Pl. XII. to be between our Eye and a plain Mirror A, A, a little on one Side, to give Passage to the Reflection towards our Eye, C. The

The Light, which falls on all the Points of the Statue, rebounds all around in every Point of the circumambient Space, as we have ſeen above; and, conſequently, this Light muſt fall on all the Points of the Surface of the Mirror, by which it is likewiſe reflected from every Part. But our Pupil takes up no more than a ſingle Point of this whole Circumference where the Light is reflected, and can receive but one of all the luminous Cones diſtributed to an Infinity. Now by the Rule, that the Angle of Reflexion, is equal to the Angle of Incidence, the ſole Cone of Light, which falls on our Eye, ſituated as in Fig. 4. is the reflected Cone A, C, A, formed by the Rays which fall upon the Mirror at the Points A, A, and which tend to make in the Bottom of our Eye, the large Opening of the Angle, b, c. For the Rays E, E, which are going to fall towards the Extremity of the Mirror on h, are reflected at a Diſtance from the Statue, and ſtill farther from our Eye. The perpendicular Rays EI return upon themſelves, and can never fall on our Eye. All the Rays E, K, K, nearer the Axis C, X, than the Rays A, A, approach to croſs one another on this Axis much on this Side of our Eye, and to be loſt at laſt on the lateral Quarters, m, m. Inſomuch, that the only Rays, which can fall on the Pupil, are the Rays A, A. The Opening of the Angle, b, c, which this Cone of Light forms at the Bottom of our Eye, gives

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us the natural Image of the Statue, as if we saw it behind the Mirror, and as far behind the Mirror, as it is actually distant from it before. For Example, if the Statue be six Feet before the Mirror, it will appear to us six Feet behind it, because the luminous Cone that conveys to us this Image, becomes narrower and narrower from the Statue to the Mirror, and from the Mirror to the Eye, as is shewn by the Figure. So that the Cone broken by the Reflection, is of the same Length, the same Figure, and of the same Opening, as if the Statue were six Feet behind the Mirror, altho' it be six Feet before it. Wherefore the Image imprinted on our Eye will be the same as if the Statue were really six Feet behind the Mirror; consequently, the Statue will appear to us six Feet behind it, and in the Magnitude that would be natural to it in this Situation.

Effect of a convex Looking-Glass.

Now let us substitute a convex Mirror, B, B, Fig. 5. Pl. XII. instead of the ordinary Mirror. The pointed Rays are those which fall upon the plain Mirror, A, A, of the preceding Figure, and there go to form in the Eye the natural Angle, b, c. But here these pointed Rays, coming to fall on the convex Surface, B, A, far from returning towards the Eye, are reflected towards d, at a great Distance from the Place where the Eye is situated. Of all the Rays that come from the Statue to fall on the whole Surface of the convex Mirror, the

the only Rays capable of being reflected towards the Pupil, are thoſe not pointed, B, B, which go to make in the Eye the Angle e, f. This Angle is very acute, in compariſon of the Angle b, c. Therefore the Statue will appear extremely ſmall, in regard of what it would do in the former Mirror, A, A.

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The concave poliſhed Surface performs likewiſe by Reflection what the convex Glaſs does by Refraction; that is to ſay, both one and the other enlarges the Objects, but it is in particular Points of View: in others the concave reflecting Surface diminiſhes the Objects like the concave Glaſs, and the convex reflecting Surface. Theſe curious Phœnomena lay claim to a little Diſcuſſion.

Effects of a concave Looking-Glaſs.

The plain Mirror is always our Rule of Compariſon. Place then the Arrow, A, B, Pl. XII. Fig. 6. overagainſt the ordinary Mirror C, D, and imagine your Eye to be before the middle of this Arrow; or, if you will, ſuppoſe your Face to be at the Place of the Arrow itſelf. Your Image reflected in its natural Magnitude will be as the ſmall reverſed Arrow, a, formed by the luminous Cone, in ſmall Points, which approaches the plain Mirror in E, E. It is to be remembered, what we ſaid above, that this Arrow, reverſed in the Bottom of the Eye, muſt appear right in our Regard. So that altho' the Image of the Arrow, or of your Face,

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be here inverted in your Eye, theſe Objects notwithſtanding will ſeem in a right Poſition.

Before this plain Mirror, C, D, place the concave Mirror, G, H, and its Concavity will collect towards the Axis, L g, the vaſt Cone of different Reflections, a very ſmall Part of which are expreſſed in the Figure. The luminous Cone in little Points, that fall on the plain Mirror in E, F, and went to form the ſmall Arrow reverſed, a, no longer keeps the ſame Track, when reflected by the concave Mirror, but is terminated very near the Mirror at the Point, m, and on that Account we can no more receive its Impreſſion.

What then is the Cone of Reflection the Eye will receive placed before the middle of the Arrow A, B? It is capable only of receiving the oblique Rays, AG, BH, which on croſſing one another ſtrike at the Extremities, H, G, of the Mirror, and return to croſs afreſh in the Eye, and there to point the Arrow, C, thrice as large as the natural Image, a, tranſmitted by the plain Mirror, C, D. But the great Arrow, C, is in the ſame Situation at the Bottom of the Eye, as the firſt Arrow, A, B, is, that is wide of it, by reaſon of the double croſſing of the Rays. Conſequently this Arrow will appear reverſed in this Place. For every right Object has its Image inverted in the Bottom of the Eye, and reciprocally all Objects, that have

their

their Images right in the Eye, appear to us reversed.

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In order to see the Image of the Arrow A, B, or rather one's own Image in a right Position, we must approach the Mirror in the Points, d, e, m, *&c.* Because we then receive the luminous Cones, that have been to strike the Mirror directly, without any previous crossing, and which, on that score, cross only in our Eye, according to their ordinary Manner. Now in these near Points of the Mirror, the Object will appear still a great deal larger than in a natural State, unless the Eye almost touches the Glass. For then our Visage appears pretty natural, because the Cone of Light one receives is very small. But in proportion as one draws back, the Visage appears more and more monstrous, for the same Reason as the Arrow d is larger than the Arrow e, being the Base of a greater Triangle.

If we place ourselves opposite to the same Mirror in the Space, o, situated between the Point where the Object appears right, d, and that where it appears reversed, C, we shall see but one Chaos of Light; because the Rays cross one another in this Space, and all the Parts of the Images are there confounded. Draw back to C, and the Image appears still larger than Nature, but reversed, for Reasons explained above. Continue to draw back, as in f, g, the Image will still remain ever reversed, but

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but will become ſmaller and ſmaller, and even ſo little, that at laſt it will equal in Minuteneſs the Image reflected by the convex Mirror. So that the Image reflected by a concave Mirror, at a middle Diſtance, is always much larger than Nature; and when this great Image is right as in m, then the more one retreats from the Glaſs, the more this Image is augmented. But when the Image is reverſed as in C, the more one recedes from the Glaſs, the more is the Image diminiſhed. The Demonſtration of theſe curious Truths is expreſſed by the ſame Cones of Light traced in the Figure, according to the Laws of Reflection.

The Magnitude of Images farther varies according to the Kinds of Eyes which receive them, and the more ſo purſuant to the different States wherein they occur.

Objects appear to us ſo much the larger, as they tranſmit to our Eye a larger Image, and a more extenſive Cone of Light. And this luminous Cone is ſo much the more extenſive, as the Object is larger or nearer to the Eye. But do we imagine that the ſame Object, at the ſame Diſtance, tranſmits to the Eyes of all Animals, and all Men, an Image of the ſame Magnitude? Undoubtedly we do not. The Magnitude of Images, and that of the Picture including them all, depend likewiſe on the Diſpoſition of the Organ itſelf. For Example, an Eye ſmaller and more twinkling than ordinary, and that has a more convex Cryſtalline Humour, receives a ſmaller Picture in Proportion, and leſſer Images; for the ſame Reaſon, as when a very convex Lens is placed on the Inſide

Inſide of the Hole of the dark Chamber, there occurs a very minute Picture. In the mean while it has been demonſtrated above, that a like Lens placed before the Eye, or on the Outſide of the dark Chamber, conſiderably enlarges Objects. This Contraſt perhaps may be perplexing; but it is no hard Matter to comprehend theſe oppoſite Effects of the ſame Inſtrument differently applied. The Sight.

The Rays that convey the Images from the Object to the Bottom of the Eye, or on the Paſteboard of the dark Chamber, form two Cones joined at the Top. The firſt Cone has its Baſe on the Object, and its Top in the Pupil, or in the Hole of the dark Chamber, where the Rays croſs. The ſecond Cone has its Top at the ſame Croſſing, and its Baſe on the Choroides, or the Paſteboard that receives the Images of the dark Chamber. The Lens one puts before the Eye, or before the Hole of the dark Chamber, is placed in the exterior Cone a little before its Croſſing. It collects in this Croſſing a larger Cone, as has been demonſtrated, and cauſes it to croſs in a wider Angle: and by that means gives a larger Baſe to the ſecond Cone, which thus renders the Images the larger. The Cryſtalline Humour, on the contrary, or the Lens one puts within the Hole of the dark Chamber, is placed in the inner Cone near its Top; which, by collecting the Rays of this Cone towards the Axis, renders the Baſe of

The Sight. it smaller. Consequently, the Images contained in this Base are also diminished by these Lens's, and that in proportion to the greater Convexity of them.

Now there is a wider Difference between the Eyes of several Kinds of Animals, than there is in Regard of all the Sorts of Lens's. It is therefore evident, that the diverse Species of Animals, and that Men in general do not see the same Objects of the same Magnitude, nor a like Quantity of Objects at a Time.

I will not insist on these known Truths; but I go farther, and aver, that the same Person, with the same Eye, sees, the same Day, and even the same Moment, Objects sometimes larger, sometimes smaller, according to certain Motions incident to this Organ, and particular Dispositions that occur.

The most frequent among these Motions of the Eye, that change the Magnitude of the visual Angle and of Images, are those which are made on our looking at a near Object, and presently afterwards at one that is remote.

The Eye is dilated, in order to see neighbouring Objects. The Diameters of its Humours, and its Lens's, are drawn into a narrower Compass, and their Surfaces become more convex. Consequently, the Eye is then in the Case of the small twinkling Eye, or the very convex Lens, which we have just been

speaking

ſpeaking of. It gives therefore on this ſcore ſmaller Images than it would do in any other Figure. But this ſame Eye is dilated, the Cloth that receives the Image is more remote, and this Image ought to be ſo much the larger. Should one of theſe Cauſes make amends for the other?

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On the contrary, in order to ſee a diſtant Object, the Eye contracts itſelf, is flatted by the Poles, and enlarged according to its Equator. The Diameters of the Humours are augmented, their Surfaces flatted, and this Eye becomes in the State of the flat Lens, which gives a more extenſive Picture. So that on this Account one ſees remote Objects larger than one would do without this Alteration of Figure: that is to ſay, Allowance being made for the Diſtance, remote Objects appear larger, than neighbouring ones do. But this ſame Eye, whoſe Humours become leſs convex, is likewiſe flatted, its Bottom advancing towards its Entrance. The luminous Cone of courſe grows ſhorter, and the Images conſequently ſmaller. Are theſe contradictory Effects equally compenſated? Or is the flat or convex Figure of the Humours predominant over the Contraction or Dilatation of the Eye? I ſhall communicate the Obſervations that ſeem to me to decide in Favour of the latter Opinion, *viz.* that the Eye on looking at a near Object, renders the Images ſmaller, notwithſtanding its Dilatation, and that the

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the Eye, which looks at a remote Object, exhibits the Images larger notwithstanding its Contraction.

Observations on the Variation of the Magnitude of Images.

Casting a random Look at a feeble Light, situated very near me, I was surprised to see this Light thrice as big as Nature, and encircled with Rays. I looked at it afterwards with Attention, and it resumed its natural Magnitude. I have since that, frequently repeated this Experiment, either with a feeble Light, or with the small luminous Point which results from a very convex polished Surface, and it always was attended with the same Success.

When I looked attentively at the feeble Light, or at the luminous Point, these very near Objects would oblige me to dilate my Eye, and to render its Humours more convex, from whence I received a small Image. I then looked at them indistinctly, that is to say, with my Eye relaxed in its most natural State, and spherical Figure, which gave its Humours less Convexity. My Eye therefore at that Time became in the Case of a flatter Lens, and thus gave me a larger luminous Point, and a more open visual Angle. One cannot make the Experiment with a strong Light, by reason its lively Impression does not permit the Eye to relax itself.

Another Time I looked, thro' the Glass of a Casement, at a very remote Country-Seat, which appeared to me sufficiently large. I afterwards

wards fixed my Eyes on the Glaſs itſelf; and it ſeemed to me a great deal ſmaller, than when I looked at it directly. Since that Time I have made repeated Experiments of this Matter, and always found the ſame Circumſtances.

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On looking directly at the diſtant Seat, my Eye was flatted. The Angle, which this Seat tranſmitted to my Choroides, was therefore larger. On fixing my Eyes on the Glaſs of the Caſement, I dilated for this near Object the Globe of my Eye, and rendered its Lens's more convex. The Image of the remote Seat, falling on theſe more convex Lens's, was there refracted to a greater Degree, and conveyed on my Choroides a ſmaller Angle, and of courſe a minuter Image.

I ſhall recount ſtill ſomething more extraordinary on this Variation of the Magnitude of the viſual Angle, or of the Image of Objects.

Images are ſmaller in very cold and very light Days.

Laſt Winter I was in the Country. In the Night it froze hard, and there fell a little Snow. On going out of my Chamber in the Morning, all Objects appeared to me ſenſibly ſmaller, than they had done the Evening before. I could not help being very much ſurpriſed. But, ruminating on this Effect, I recollected that a long Time ago in a dry and clear Seaſon, I had frequently been aſtoniſhed to ſee Objects with a Preciſion, where I had a confuſed Notion that there was ſomething more

in

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in the Matter than a bare Exactness. These confused Notions are the Seeds of Discoveries. This in particular had prepared me to remark in the preceding Experiment the Diminution of the Magnitude of Images by the hard Frost and the Snow; and some few Reflections soon made me perceive, that my Discovery was a necessary Consequence of the Nature of the Eye, and of the Principles I have been expounding.

The Images painted in my Eye are smaller in Proportion to the Smallness of the Diameter of the Eye, and the greater Convexity of its Humours. *Peter* sees Objects smaller than I see them, if he has smaller Eyes, and more convex than I have. If there are Times, Days, or Moments, when I myself have Eyes as small, as contracted, and as convex as those of *Peter*, I then see Objects as small as he sees them, and smaller than I see them ordinarily.

This is exactly the Case of Eyes, struck with the Cold of Frost, and the Brightness of Snow. Both the one and the other of them, making a strong Impression on these Organs, excite in them a forcible Contraction. The Eyes struck in this Manner are lessened in all Directions, and principally according to their Equator, by the Contraction of the Iris and Corona Ciliaris. All the Humours participate of this kind of Condensation; and, consequently the Eye is smaller, more convex, and receives of course a smaller visual Angle, and not so large an Image.

I

I became notwithſtanding appriſed of this Diminution of Images very accidentally. As theſe diminiſh univerſally after the ſame Manner, there remains no farther Rule of Compariſon. On which Score this is no ſenſible Phœnomenon, and, in order to perceive it, I muſt have had the Magnitude of the Images of the preceding Evening very preſent to my Idea. But it is not the leſs certain, as the Figure of the Eye contributes to the Magnitude of Images, that we muſt neceſſarily ſee Objects the more or leſs large, proportionably to the greater or leſſer Degree of Elaſticity the Temperature of the Air, or our Health, imparts to our Solids, or of Rarefaction accruing from either of thoſe Quarters to our Fluids. Thus in hot, faint, cloſe, hazy Weather, in a weak and languiſhing State of Health, and in certain plethoric Caſes, the Eye being then relaxed and dilated to a greater Degree, we ſee Objects ſo much the larger, and in a cold, dry, clear Seaſon, and in a good Diſpoſition of the Organs, they appear ſmaller: inaſmuch as our Fibres and our Eyes, from theſe Contingencies, acquire a greater Elaſticity and Contraction, and our Fluids become much leſs rarified.

Since I made this Diſcovery, and have been guarded againſt the Rule of Compariſon, I plainly perceive that a very illumined Object ſeems ſmaller, and an Object feebly ſupplied with Light appears larger. The Reaſon of this

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this is evident. A ſtrong Light puts the whole Globe of the Eye on contracting itſelf, and a feeble one leaves it relaxed and dilated.

The ſecond Rule, whereby to judge of the Magnitude and Diſtance of an Object, is the Confuſion or Clearneſs of its Image.

How ſure and geometrical ſo ever be the Opening of the viſual Angle to determine the abſolute Magnitude of Images, it cannot notwithſtanding ſingly conſtitute a Rule for judging of the Magnitude of Objects relatively to their different Diſtances. It will very well decide between two Objects at an equal Diſtance, which of them is the larger; but it will never alone determine this Diſtance of Objects, nor conſequently their Magnitude, which diminiſhes in Proportion to the Diſtance. The Reaſon of this Uncertainty of the viſual Angle is, becauſe in the ſame Angle, Fig. 1. Pl. XII. one may place a Series of Objects of different Magnitudes, 2, 3, 4, 6, provided they are ranged at a Diſtance proportionable to their Magnitude.

All theſe Magnitudes, 2, 3, 4, 6, would therefore form in the Eye the ſame Angle, and have there an Image equally large, tho' they would each of them be of unequal Magnitude.

The viſual Angle, as intirely geometrical as it is, will then deceive us, if we compare it with the Degrees of the Diſtance of the Object. A Tennis-Ball, ſeen at the Diſtance of ſome few Inches, will form a viſual Angle as large as a Turret a hundred Paces off; and on that Account this Ball will appear as big as ſuch a Turret, in caſe the Proximity of the Ball does

not

not oblige one to abate as much of its apparent Bignefs, as the Diftance of the Turret would make one add to the Magnitude of its Angle. I therefore rate each Magnitude of the vifual Angle, at its juft Value, by the Comparifon I form of the refpective Diftance of the Objects. But by what Rule fhall I judge of this Diftance? By the *Confufion of the Image* itfelf, contained in the vifual Angle, or by the *Body of Vapours*, which the Diftance raifes around the Object, and alfo by the Length of the optic Angle formed by the Concourfe of the optic Axes of each Eye.

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I obferved above that, on looking at an Object with both Eyes, both the Axes are united on this Object. When this Object is near, as O, Fig. 2. Pl. X. the Angle formed by thefe Axes is very fhort, or open; and both Pupils are turned in a greater Degree one towards the other. On the contrary, when the Object is remote, as G, were it on the fame Line as the former, the Pupils would recede one from the other to form a longer and more acute Angle; and it is conceived, that in a great Diftance the Pupils become parallel.

We are not infenfible, that thefe Motions, and thefe Situations of the Pupils and optic Axes, vary according to the Diftances of Objects. We are habituated to diftinguifh them, and thereby fufficiently enabled to form a Judgment in regard of thofe Diftances.

I

The Sight.

I do not at all doubt but that the more or less extended Series of different Bodies, situated between the Objects and us, is a farther Assistance in respect of this Judgment. But the Concurrence of the optic Axes of both Eyes is itself necessary in order to distinguish exactly this Series of intermediate Bodies. So that this Concurrence of the Axes, and the Length of the Angle they form, is the first Principle of this Judgment. From thence it happens that when we see but with one Eye, we no longer distinguish Distances; and that looking thus even from very near, we cannot lay the End of our Finger on any set Place. Nay, this Finger will even hide the destined Object, and were it a Foot off, the Finger corresponds with it as justly, as if it were only at the Distance of a Line. But if we open the other Eye, this, which sees our Finger and the Object sideways, will discover between them a great Space, if they are a Foot distant, and but a small one, if they are very near; and by that means we may place our Finger with Certainty on the designed Object. See Pages 199, 200, &c.

Cause of the Body of Vapours, which covers remote Objects, and the Use Painting makes of them.

The Confusion with which we see an Object, is the second Rule to judge by, that it is very remote. This Confusion of the Image of a distant Object proceeds from the Air, and Vapours, which extinguish Part of the Rays that compose this Image.

The

The Narrownefs of the luminous Cone of remote Objects, contributes likewife to this Extinction. It is even aftonifhing, that fo fmall a Filament of Image fhould not be intirely effaced on meeting with fuch a prodigious Quantity of Obftacles.

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The Confufion of diftant Objects is therefore a Phœnomenon the moft conformable to the Laws of Phyfics. It is even a Fact eftablifhed thro' the whole Syftem of Nature, which no one can be unapprized of, if they will but open their Eyes. Painting, the Mimick of Nature in this Kind, in order to exprefs the Diftance of Objects in Perfpective, after the Diminution required by the vifual Angle, covers thefe Objects with a Lay of Vapours proportioned to that Diftance. The Degree of this Lay conftitutes even one of the moft delicate Circumftances of the Art. In a Landfcape, an Artift will reprefent on the Canvas a Rat and a Camel of equal Magnitude. Becaufe the Rat, with glaring Colours, will project a good deal, and the Camel, fcarce vifible, will feem to be loft in a Deepning, where we ourfelves lofe the Idea of the Cloth on which he is painted. In Nature, we fee above a Wall two Steeples of equal Magnitude; but we fee one of them with the Confufion that ftill refults from any confiderable Diftance, while we view the other very diftinctly, even to the Ornaments of Architecture. From whence we judge the latter to be very near us, and the

The Sight. other to be as remote. And tho' their Image be of the same Magnitude, we conclude nevertheless, that the distant Steeple is by far larger than the other; inasmuch as we know by Experience, that Distance diminishes Objects; and that a remote Object, which appears as large as a neighbouring one, must necessarily be a great deal larger than this latter. It is by the same Rule, that the Eye being deceived, sees Objects the larger in foggy Weather, and the Moon in the Horizon a great deal bigger than in any other Part of the Heavens. A Fog, by covering these Objects with thick Vapours, makes them appear more remote than they are; but as they cause no Diminutionof their Bulk, we imagine them more considerable. On taking a Walk in a Fog, any Person in view seems to us of gigantic Stature; by reason we see such a Person confusedly, and as at a great Distance; when, the Object notwithstanding being just upon us, a very large Image is transmitted to our Eye. Now we judge a remote Object to be large, that imprints on the Eye a large Image. But in this case we soon recover from the Mistake, and by that means perceive the Origin of it. For we are surprised to find ourselves in an Instant quite near this Person, whom we imagined to be at so great a Distance, and whose Size no longer appears extraordinary.

How Fogs enlarge Objects.

It

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Why the Moon appears larger in the Horizon than in her Meridian.

It is by the ſame Enchantment, that the Vapours of the Horizon make us ſee the Moon as confuſedly, as if ſhe were as far off again; and theſe ſame Vapours diminiſhing nothing of the Magnitude of the Moon's Image, the Soul, having no Idea of the real Magnitude of this Planet, concludes her as big again: becauſe on ſeeing an Object two hundred Paces diſtant, under an Angle as large as that of another Object ſeen at a hundred, ſhe judges the Object two hundred Paces diſtant, as large again as the other, unleſs appriſed of the real Magnitude of theſe Objects.

Father *Mallebranche*, followed almoſt by all our Naturaliſts, explains this apparent Magnitude of the Moon on pretty near the ſame Principles. But he ſays one judges the Moon at a greater Diſtance in the Horizon, becauſe there then appears between her and us a long Series of Mountains, Vallies, Woods, *&c.* Whereas in her Meridian ſhe ſeems only a little above our Steeples. Now a Word or two deſtroys this Syſtem. If we look at the Moon in the Horizon over a Wall, thro' a Paper-Tube, or with a Teleſcope, we ſee no more of theſe Mountains, Vallies, *&c.* thoſe Indications of her Diſtance, and yet ſhe ever appears larger than ſhe is. Some other Body therefore, foreign to theſe Vallies and Mountains, muſt interpoſe to enlarge her, at leaſt in my Imagina-

R 2 tion.

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tion. And what can this be but the Vapours of the Horizon itself?

This Effect has always been ascribed to Vapours; but these Vapours have been thought to enlarge the Moon's Image, as a Lens enlarges Objects. A single Astronomical Observation has quite disconcerted this System. The Image of the Moon seen thro' large Telescopes, and measured by the Micrometer, seems as small in the Horizon, as in her Meridian. I refer the Matter to Astronomers. They are Persons of too great Penetration to suffer themselves to be imposed on by Telescopes. Their Observation confirms my Opinion. In the mean while I act with Sincerity, and shall communicate an Experiment, which has induced me to conclude, that Refraction bears some Part in regard of the Moon's Magnitude in the Horizon, let what Use soever be made of it.

Experiment on the Refraction of the Atmosphere of the Horizon, in relation to the Stars, and the Augmentation of their apparent Magnitude in this Region.

I procured a Glass Vessel, A, B, Fig. 1. Pl. XIII. shaped like a Quarter of the Atmosphere taken with a Level on the Surface of the Earth, C, or having for its Base a Tangent of this Surface. This I filled with Water. I placed a Crown-Piece in E, to represent the Stars a little below the Horizon, and my Eye in B, the Horizon of my Machine. I saw the Crown before it was at the Height of this Horizon, and saw it considerably enlarged. Whereas placing it at D, representing the Meridian, and my Eye in C, I saw the Piece in its natural

Plate. XIII.

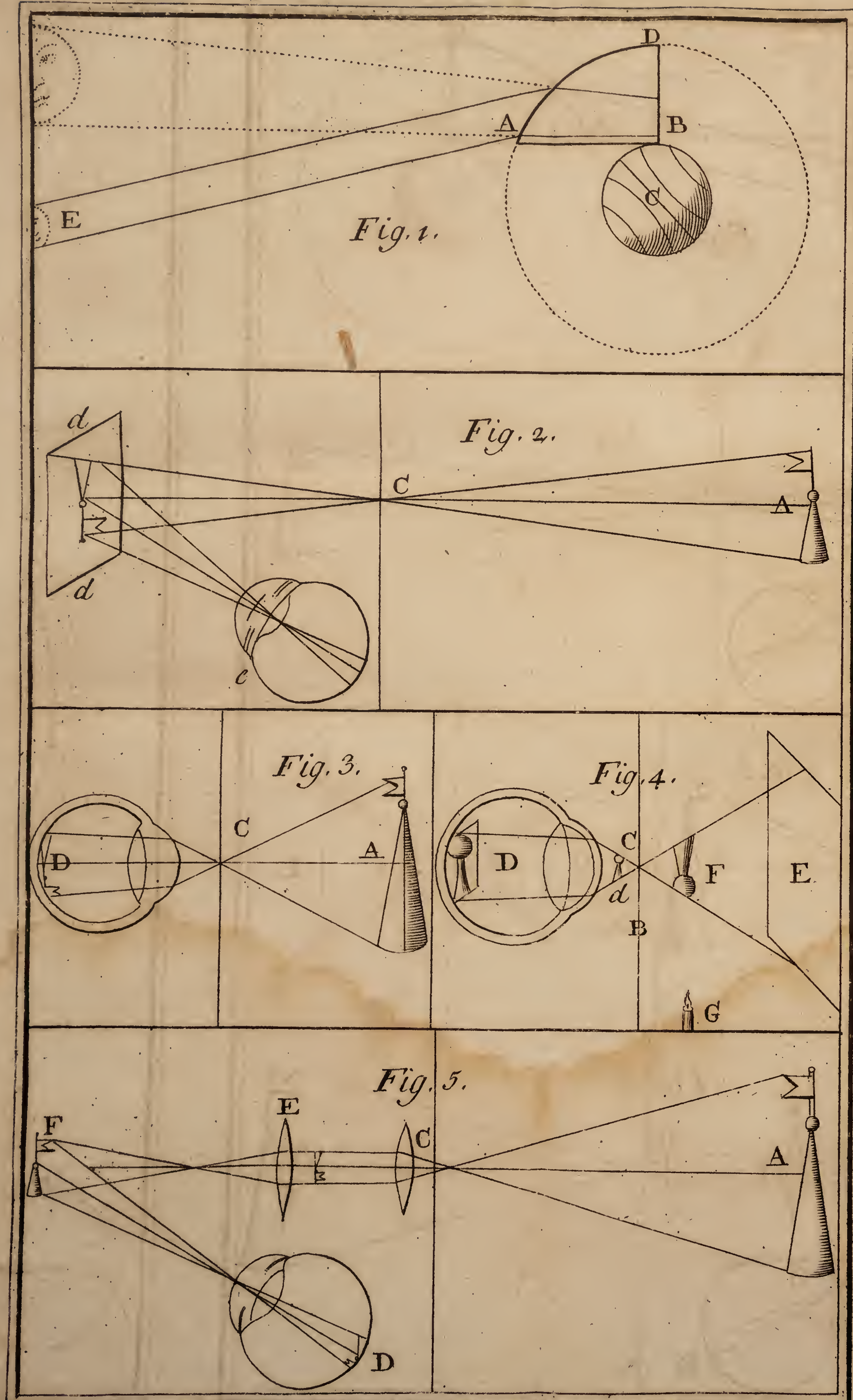
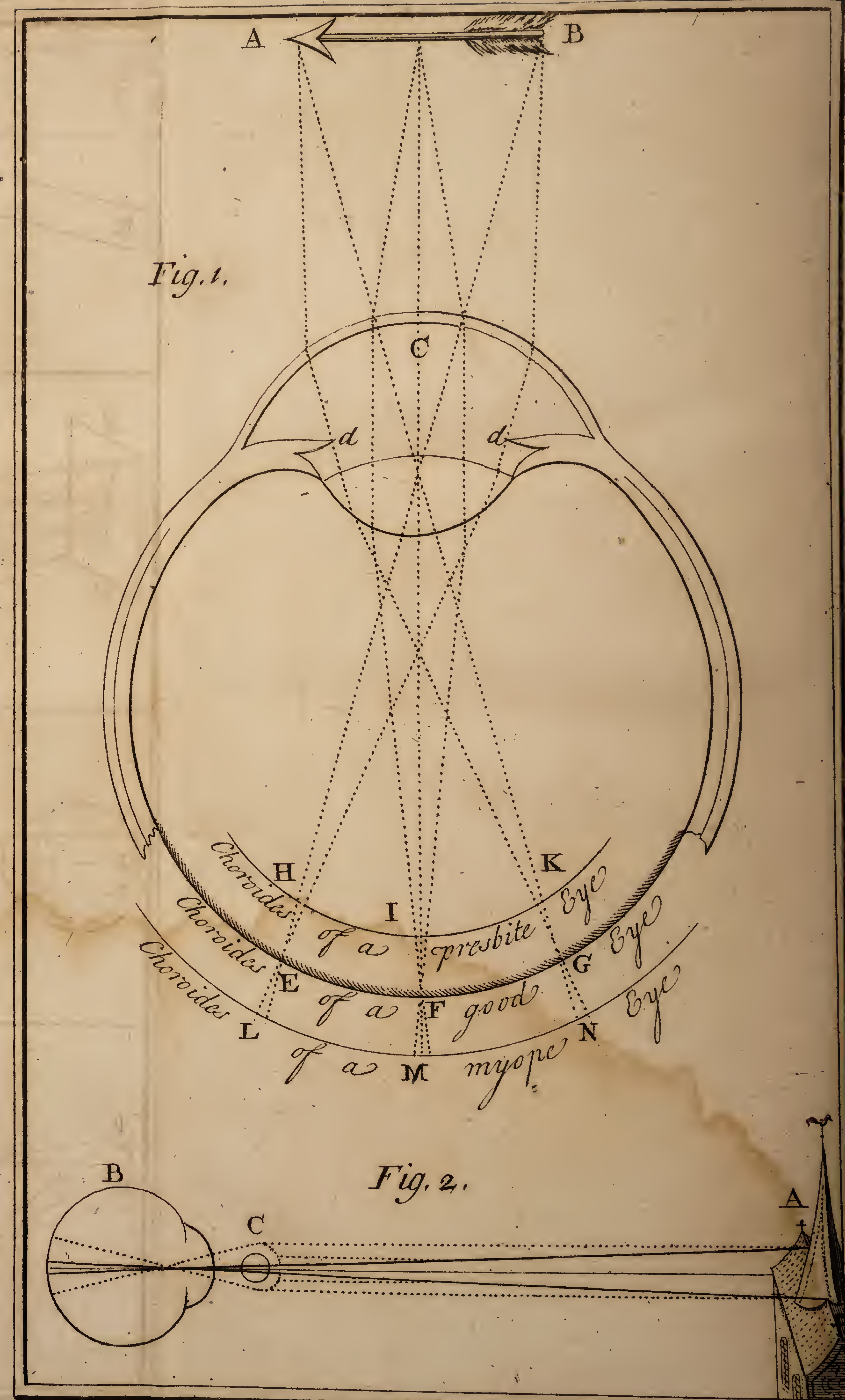


Plate. XIV.



ral Magnitude. I ſaw it here in its ordinary Magnitude, becauſe its Image fell perpendicularly on my artificial Atmoſphere, and reached my Eye without any Refraction, or Alteration. I ſaw the Crown-piece before it was in the Horizon, A B, of my Machine, by reaſon, its Image falling obliquely on the Surface of this tranſparent Machine, it was conveyed to me by Refraction, before the Crown correſponded perpendicularly with this Place. This Piece appeared to me conſiderably enlarged, becauſe its Rays were refracted convergently, as expreſſed in the Figure. The Stars are ſeen on the Horizon, like the Crown-piece, before they really are there. Would not this ſame Refraction, that makes them thus advance by their Images, enlarge them likewiſe as it does the Crown? This ſeems to me a Conſequence neceſſarily flowing from the Laws of Dioptrics: and, in that Caſe, this Cauſe might very well concur with that I have above aſſigned for the Moon's and Stars appearing larger in the Horizon than in any other Part of the Heavens.

The third Rule whereby the Soul judges of the Magnitude and Diſtance of Objects, is to compare them with the known Magnitudes.

A third Rule, whereon the Soul founds its Judgments of the Magnitude and Diſtance of Objects, is the Knowledge we have of the natural Magnitude of certain Objects, and of the Diminution accruing to them from Diſtance. An Artificer, ſeen on the Top of a Steeple, appears at firſt no bigger than a Bird. But when I deſcry him to be a Man, I imagine him five

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or six Feet high, because this Measure is the ordinary Standard for Men: and at the same Time, by Comparison, I judge the Cross and Weather-Cock of this Steeple to be of much more considerable Bulk, than I believed them to be before. It is thus that Painting will express a prodigious Giant in the Space of an Inch, by placing near him a Person of common Stature, that shall reach no higher than his Ancle-Bone, and a Tree, or a House, that shall not exceed his Knee. The Comparison strikes us, and we imagine at first Sight the Giant to be of an enormous Size, altho' in reality he takes up no more than an Inch of Canvas.

The Judging of the Magnitude and Distance of Objects, is an Art of Habitude; but it is still an Art, and its Rules are real.

Tho' this Judgment be a natural Consequence, as well as all others the Soul forms on the Situation, Simplicity, Distance, *&c.* of Objects, both the one and the others are made nevertheless without Reasoning, inasmuch as they are universally founded on a long Habitude of seeing; whence they degenerate with us into a kind of Instinct. Ideots, Infants, and even Beasts reason sufficiently for this, after they have lived long enough to have acquired this Habit *. This Circumstance does not at all detract from the Necessity and Advantage of the foregoing Rules. It is a Proof only, that the repeated Use of these Rules forms in us a Facility of drawing

* It is observable by the bye, that this simple Use of Vision is a farther Proof, that Animals think, reason, and judge, after their Manner.

drawing Confequences almoft without being apprifed of it.

All Habitudes are only this, *viz.* a Facility acquired by repeated Acts. But thefe Acts, which are the Bafis of the Habitude, neceffarily fuppofe Rules. Thefe Rules are executed with Difficulty before a Habitude is acquired; but afterwards we put them in Practice with Eafe, with a greater Degree of Affurance, and as it were mechanically: This is the whole Difference.

So that altho' the vifual Angle be altogether geometrical, altho' the Lay of Vapours that covers remote Objects be intirely phyfical, and the Confequence drawn from the Comparifon of known Magnitudes be perfectly logical, the Judgment, or rather the Eftimation of the Diftance and real Magnitude of an Object, is neverthelefs an Art of Inftinct acquired by Habitude, where Logic is of no Service in Nature. Infomuch, that in Cafes where the Eyes deceive us, whether thro' the Difficulty of applying the preceding Rules, or thro' the Abufe of the Rules themfelves, the greateft Logicians are miftaken as well as others; and it is in this confifts the whole Magic of Painting.

But from whence proceeds this Uncertainty in regard of the moft beautiful and moft ufeful of our Senfes? How in particular can we account for thefe Errors of Vifion relating to the Magtude, Situation, &c. of Objects? The Reafon

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of all this is, becauſe the Meaſure of the Number of Magnitudes and Diſtances is not the proper Object of the Sight, but that of the Touch, or rather that of the Rule and Compaſs. The Sight, properly ſpeaking, has no other Province, than that of Light and Colours. The celebrated Monſ. *de Voltaire*, in his Elements of Sir *Iſaac Newton*'s Philoſophy, relates a fine Obſervation, that confirms the Truths we have been eſtabliſhing.

No one undoubtedly could be more in a Condition of explaining to us how Viſion is performed, and after what Manner are known the Magnitude, Diſtance, Situation, and Figure of Objects, than one born blind, to whom has been procured the Faculty of ſeeing, at an Age capable of expreſſing what paſſed in his Ideas.

A ſingular Obſervation confirming the preceding Doctrine.

" But where to find (ſays this renowned " Author) the proper blind Object to decide " inconteſtably the Point in Queſtion? In ſhort, " in the Year 1729, Mr. *Cheſelden*, one of " thoſe famous Surgeons, who join Dexterity " of Hand to the greateſt Lights of Genius, " having imagined it poſſible to give Sight to " one born blind, propoſed the Operation *. " It was with Difficulty the blind Perſon was " brought to conſent to it. He had no extra-

" ordinary

* This Blind was born with a Pupil intirely cloſed, and the Operation conſiſted in making an Opening in this Part.

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" ordinary Notion, that Viſion could make any " great Addition to his Pleaſures. Independently of the Deſire that had been inſtilled " into him of learning to read and write, he " had no manner of longing after Sight. He " verified by this Indifference, continues Monſ. " *de Voltaire*, that it is impoſſible to be unhappy " thro' the Privation of a Good, of which one " has no Idea. But, be that as it will, the " Operation was performed, and ſucceeded. " This young Man at about fourteen Years of " Age, ſaw the Light for the firſt Time. It " was a good while e'er he could diſtinguiſh " either Magnitude, or Diſtance, or Situation, " or even Figure. An Object of an Inch " placed before his Eye, and that hid a Houſe " from him, appeared to him as big as a " Houſe. All he ſaw ſeemed to him at firſt " to be upon his Eyes, and to touch them, as " Objects of the Touch do the Skin. He " could not diſtinguiſh what he had judged " round by the Help of his Hands from that " he had concluded angular; nor diſcern with " his Eyes, if what his Hands had perceived " to be on high, or below, was in effect " high or low *. He was ſo long from " knowing Magnitudes, that, after having at " laſt conceived by the Sight, that his Houſe

" was

* This confirms what I was ſaying above, that it is by a Reaſoning of Habitude, that the Soul rectifies Objects, and judges that an Image, reverſed in the Bottom of the Eye, comes from an external Object in a right Situation.

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"was bigger than his Chamber, he could not "apprehend how Viſion could give this Idea. "It was only at the End of two Months Experience "he could form a Notion, that Pictures "repreſented ſolid Bodies. And when, after a "long Groping with this new Senſe of his, he "had perceived that Bodies, and not Surfaces alone, "were painted in thoſe Pieces, he felt "them with his Hands, and was aſtoniſhed not "to find by the Touch thoſe Bodies ſolid, "whoſe Repreſentation he began to have a Perception "of; and wanted to know which it was "deceived him, the Senſe of the Touch, or "that of the Sight."

How Objects *are ſeen* distinctly.

To diſcern a *ſingle* Object, it is ſufficient, as we have ſeen, to direct the Axes of both Eyes on the Object. To diſcern it *diſtinctly*, this firſt Motion is neceſſary but inſufficient.

What conſtitutes a diſtinct Image.

An Image is diſtinct, when all the Points of the luminous Cone that form it meet in the ſame Proportion as they preſerve on the Object itſelf, without Confuſion, or Space, without any Mixture of foreign Rays, and without the Organ's being affected by this regular Collection of Rays either in too lively or in too feeble a manner.

Or, in other Words, an Image is diſtinct, when all the Points of Light, and the Mixtures

of

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of Shade that form it, are ranged in succeſſive Order, as they are on the Original itſelf; ſo that ſeveral of theſe Points or Mixtures of Shade do not center in a ſingle one, or leave any Spaces between them, that are not in the Original; or, in ſhort, make any Impreſſion, that is not abſolutely proportioned to the Senſibility of the Organ. For the one or other of theſe Defects renders an Image confuſed.

That all the Points of a luminous Cone conveying an Image may fall near one another in the juſt Proportion, which renders an Image diſtinct, the Cloth that is to receive theſe Rays muſt be placed exactly in the Degree of Diſtance E, F, G, Fig. 1. Pl. XIV. from the croſſing dd of the luminous Pencils, at which Diſtance occurs this juſt Proportion, this exact Order of luminous Points, and of the Points of Shade. Let us form to ourſelves a clear Idea of this juſt Re-union of luminous Pencils, at a certain Point. And, to this End, let us recollect, that each Body ſcatters around it the Light that ſtrikes it. So that each Pencil of Light, in Contact with a Point of a Body, rebounds on enlarging itſelf continually; inſomuch, that this Point of the Body makes the Top of the Cone, which forms the reflected Pencil. Take in the Arrow A, B, Fig. 1, three of theſe Points, or of theſe Pencils, amongſt the prodigious Number of thoſe that reflect from the Arrow, and form Cones all around. At whatever Diſtance you

The Sight. place yourſelf, your Eye will receive a Cone from every one of theſe Points, and the Baſis of theſe Cones will fall upon your Eye. But to procure a diſtinct Image at the Bottom of the Eye, that is to ſay, to cauſe there a Re-union of each Pencil in one Point, as in the Original that tranſmits it, and in the ſame Order, it is ſufficient that theſe Pencils pierce the Eye: becauſe the Refraction in breaking ſeveral of the oblique Rays, d, d, and few or none of the others, C, the luminous Pencils muſt neceſſarily meet in E, F, G, as they did on the Object A, B. The Points E, F, G, form therefore the optic Plain, the Place where the Image is diſtinct. It is there then, where we ought to fix the Cloth, the Paſteboard that receives an Image, and in particular the Choroides. If this be more advanced in H, I, K, it will fall in with the Pencil farther enlarged, and the Image will become confuſed, becauſe theſe enlarged luminous Points do not render it like the Original; and, being beſides diſperſed, are mixed with the collateral Pencils, which we muſt ſuppoſe in the Circumference of theſe to be in infinite Number. If the Choroides, or the Cloth, be at a greater Diſtance, as in L, M, N, the Point of Re-union will be overſhot, and the Cloth will fall in with the Beginning of a new Croſſing of Rays, a new Scattering, and a new Divergence of each Pencil, and conſequently the Image will be very confuſed.

So

So that after the Croſſing of all the Pencils of Light towards the Cryſtalline Humour d, d, where all the Rays are confounded in a Heap, as it were, even to the new Croſſing of each Pencil in L, M, N, there are only the Points E, F, G, where the Pencils are diſtinctly re-united, and re-eſtabliſhed in the order they preſerve on the Original from whence they are reflected.

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This Point is not the ſame in regard of a diſtant Object, and one near at Hand. The Rays reflected by a neighbouring Object arrive at the Eye more divergent, and more ſcattered, and their Cone forms a more open Angle. They muſt therefore re-unite at a greater Diſtance, and beyond the Focus of the Cryſtalline, even where the Rays of the Object, were it too near, would not be reunited at all, but would fall parallel to the Bottom of the Eye. It is the Reaſon why we diſcern no Object approaching too near the Pupil, or diſcern it very confuſedly.

The Reaſon why the Point or the Image of near Objects becomes diſtinct, is because it is more remote from the croſſing of the Rays, than the Point where the Image of remote Objects appears clearly.

The Rays proceeding from a diſtant Object are almoſt parallel, when they arrive at the Eye. Now ſuch Rays, by the Laws of Refraction, muſt neceſſarily re-unite their Pencils at the Focus, or very near the natural Focus of the Eye, and conſequently a great deal ſooner than thoſe of neighbouring Objects.

Let me add, that Rays reflected by a neighbouring Object are Traces of Light darted from

The Sight. from very near, and that the Increaſe of their Force is in Proportion to the Proximity of the Object, that darts or reflects them. Their Reſiſtance therefore in Regard of Refraction is ſo much the greater, and the luminous Pencils are re-united of Courſe at a remoter Diſtance. On the contrary, the Rays reflected by a diſtant Object are weakened in the long Track they traverſe; their Force is loſt, and extinguiſhed by little and little, as is the Caſe of all communicated Motion. Theſe Rays then give way more eaſily to the Powers of Refraction, and conſequently their Pencils are ſooner re-united. The luminous Pencils then of neighbouring Objects are, in Regard of the luminous Pencils of Objects at a Diſtance, almoſt what a red Ray is in Reſpect of a violet-coloured Ray; that is to ſay, the Pencils of diſtant Objects are more refrangible. Therefore they muſt for all theſe Reaſons be re-united ſooner, or nearer the Cryſtalline Humour, than the Pencils reflected from neighbouring Objects. This is no ways here a ſimple Conjecture, mere phyſical or geometrical Reaſoning, but real Matter of Fact, ſubjected even to occular Demonſtration.

Be placed in a Chamber over againſt the Window: hang at this Window a String, a Piece of Wire, *&c.* Preſent to theſe Objects, in the middle of the Chamber, a lenticular Glaſs, in order to receive their Image, and, at the ſame Time, that of Objects from without the

the Chamber. Behind the Lens hold a white Pafteboard, on which thefe Images may be painted.

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You will obferve, that, when the Objects from without fhall be painted clearly on the Pafteboard, the Image of the String hung at the Window will appear on it confufed, and like an enlarged Shade. If you would have a diftinct Image of this String, you muft place the Lens at a Diftance from the Pafteboard, and then the Image of the Objects from without the Chamber will be confufed in their Turn. If afterwards you have a Mind to fee diftinctly the Image of thefe Objects from without, you muft advance the Pafteboard to the Lens, or the Lens to the Pafteboard.

The Motions of the Eye in order to fee diftinctly both near and remote Objects.

The Humours of the Eye perform the Office of a Lens, and the Choroides is the Cloth that receives the Images. Therefore, in order to fee diftinctly, it is neceffary, when we look at a very near Object, that there fhould be a greater Diftance between the Cryftalline and the Choroides; and that, when we look at an Object more remote, the Cryftalline and the Choroides fhould nearer approach one another, without which the Image is confufed.

It is the Reafon why, on looking at a diftant Object, the Eye contracts itfelf, and becomes flatted, its Bottom advancing towards the Entrance of this Organ, in order to meet the lumi-

nous

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nous Cone, that re-unites its Pencils nearer their crossing.

The Flatness of the Humours adds likewise to the Feebleness of this Cone, in producing a less Refraction. For the flatter a Lens is, the less it refracts Light.

These flatter Humours seem to oblige the luminous Pencils to assemble at a greater Distance, or have a longer Focus, like flat objective Glasses. This would be Fact, were the Flatness of these Humours as considerable as that of those Glasses. But as it is moderate, it is not even sufficient to supply intirely the Refrangibility of Rays. It can but partly make way for the luminous Pencils; and the Bottom of the Eye which comes forwards has so much the less to do. It is very obvious how much this Concurrence contributes to render this Mechanism easy. It is an Advantage Glasses are deprived of, that have solid Lens's; and on that Account one is obliged considerably to shorten them on looking at distant Objects.

This small Flatness of the Humours of the Eye causes likewise the total Cone of Light to pass there in a greater Angle, and imprint on the Choroides a larger Image; for the same Reason, as when I put a flatter Lens to the Hole of the dark Chamber, I have the Images of external Objects to a larger Dimension. See p. 231, 232, &c.

When

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When, after having looked at a diſtant Object, and ſurveyed it in the Magnitude we have been ſpeaking of, one looks afterwards at one that is near, the Eye from being flat, as it was, becomes lengthened, in order to determine the Choroides to the Point of the Union of the Pencils. The Humours are more convex, and refract Light to a greater Degree; and this increaſed Refraction was neceſſary to collect the very divergent, very ſtrong, and very little refrangible luminous Pencils of theſe neighbouring Objects. Notwiſtanding this great Refraction, ſtill the Rays darted from too near a Diſtance, get a little the better of it. There remains to them nevertheleſs Superiority enough to draw back their Focus, and the lengthened Figure of the Eye comes very apropos to go and receive, and finiſh, what the Convexity of the Humours had begun; but this Convexity ſaves it ſtill a Part of the Way.

Humours more convex give ſmaller Images, as does a more convex Lens in the dark Chamber. So that altho' neighbouring Objects appear larger, by reaſon they tranſmit a larger Angle to the Eye, this Angle notwithſtanding is leſs than it would be, in caſe the Eye could be lenthened without rendering likewiſe its Humours convex; and Objects would appear larger, if it could lengthen itſelf, and preſerve its Humours flat, in the manner they are, when one ſurveys a diſtant Object. Diſtant Objects

The Sight. appear to us then a little larger, and nearer Objects somewhat smaller than they would seem to us, were the Humours or Lens's of the Eye always under the same Configuration.

It is for this Reason that, when we see a distant Object, while we have our Eyes fixed on a neighbouring Object over against it, the distant one appears to us a great deal smaller and more confused, than when we look at it itself directly. We see it smaller, for Reasons given p. 235. We see it confused or surrounded with Rays, because the Choroides being drawn back, is no longer at the Point where this feeble Cone is subsisting distinctly.

From hence it happens, that there are Persons in the World, that can only see, distinctly, Objects almost under their Eyes; because their Choroides is naturally at too great a Distance from the Crystalline Humour, for the distinct Image of remote Objects to be able to reach this Choroides. Others, on the contrary, cannot see Objects distinctly unless they are very distant; by reason their Choroides is so near the Crystalline Humour, that the Image of neighbouring Objects is not yet formed, when the luminous Cone arrives at the Choroides.

The Myope, or near-sighted Eye.

The *Myopes*, or those that can only see Objects very near, have the Choroides too far off from the Crystalline Humour, or from the Crossing of the Rays; either because their transparent Cornea projects too much, the

Crystalline

Cryſtalline Humour is too convex, and too ſtrong a Refraction makes the Rays croſs too ſoon: or elſe becauſe, with an ordinary Refraction, their Globe of the Eye is too big, and too much diſtended, or the Space of the vitreous Humour too large. In both theſe Caſes the optic Point, or the diſtinct Formation of the Image, is on this Side the Choroides. So that when the Image falls on this Choroides, it is already diſconcerted, the Pencils are already divergent, as in L, M, N, Fig. 1. Pl. XIV. Theſe Sort of People thruſt their Eyes almoſt upon the Objects; in order to lengthen the Focus by this Proximity, and make the optic Point reach the Choroides. They alſo ſucceſsfully make Uſe of a concave Glaſs, that lengthens the Croſſing of the Rays, and the Point where the Image is diſtinct. But Age, which diminiſhes Abundance of the Liquids, and the good Plight of the Eye, as well as of all other Parts, generally corrects this Defect.

The SIGHT.

Thoſe who diſcern nothing but at a great Diſtance, have the Choroides, H, I, K, too near the Croſſing, d, d, of the Rays; either becauſe they have the tranſparent Cornea or the Cryſtalline Humour too little convex, or elſe the vitreous Space too ſmall.

The Preſbite Eye, or that which ſees well only at a Diſtance.

If they have the Cornea, or the Cryſtalline Humour too little convex, the Refraction is feeble, the Croſſing is made at too great a Diſtance, as is the Re-union of the optic Pencils.

The Sight.

So that the inverted Cone gains the Choroides in H, I, K, before the Pencils are united, and before the Image is distinctly formed, as it is in E, F, G.

Tho' the Refraction and Crossing are as usual, yet if the Apartment of the vitreous Humour be too small, too short, or flatted, the Choroides will be still on this Side the optic Point, and will receive no distinct Image, unless that of very distant Objects, that have a shorter Focus, and require precisely a Choroides near the Crystalline Humour, as these Presbite Eyes have; a common Defect in old People from a general Aridity of the Parts. This Defect is corrected with convex Glasses, Microscopes, and a Lens which augments the Refraction, and renders the Crossing of the Rays and their Focus shorter. But this is the sole Resource remaining to those who labour under this Inconvenience. For the Presbite Eye has not, like the Myope, the Advantage of being amended by Age. Time, on the contrary, serves only to render its Condition worse.

A well formed Eye is therefore that, wherein the Image of Objects, at a middle Distance, falls distinctly on the Choroides without any Violence offered to this Eye; which supposes a regular Figure of the Parts of the Eye. But a good Eye is that, which adds to this regular Conformation, the Talent of seeing distinctly at all Distances; because it has the Power of

metamor-

metamorphosing itself into a Myope, or dilated Eye, when it surveys very near Objects; or into a Presbite, or flatted Eye, when it looks at Objects that are very remote.

How the Eye is expanded to view near Objects, and flatted for those at a distance.

This Power the Eye is endued with of dilating or contracting itself, can only reside in the Muscles, and ciliary Fibres, that surround and move the Crystalline Humour.

When we look at a remote Object, we twinkle the Eye-lids, that seem to press upon the fore Part of the Globe, in order to flat it. The Eye seems also to sink to the very Bottom of the Orbit, by the Contraction of all the streight Muscles, which line this Bottom with their inflated Bellies; and, drawing by their Tendons the anterior Hemisphere against it, must flat of course both the one and the other by its Poles, and make the Choroides by that means approach the Crystalline Humour, and perhaps render that Humour itself flat.

When, after having viewed a remote Object, we look immediately at an Object that is very near us, situated on the same Line as the former, we are sensible of a Rotation, and a violent Agitation inwardly, tho' no outward Motion be perceived in the Globe of the Eye. The Eye-lids are dilated, and the Eye seems to advance out of the Orbit. Being pressed laterally, or according to its Equator by its Muscles, it becomes flat, pursuant to this Dimension, and is dilated by its Poles. The Corona Ciliaris is

The Sight. is at the same time contracted, and determines likewise the Portion of the Globe that is fastened to it towards the Axis, and the Crystalline Humour towards the Pupil. By that means it so much contributes to the Dilatation of the Eye, and to the causing a greater Distance between its Bottom and the Crystalline Humour. It is even possible, that by pursing up this thro' its whole Circumference, in concert with the lateral Pressure of the intire Globe by the Muscles, it helps likewise to render this Lens more convex. The Crystalline Humour is not of sufficient Solidity to be unsusceptible of these Alterations; and the small Quantity of Humours besides, which lubricate the Inside of its proper Coat, give Liberty enough to this Coat to change also the Figure of its Surface. Cannot one add to these Proofs the Observations in p. 232, *&c.*? In short, it is very requisite, that the Crystalline Humour, and its ciliary Fibres, should be capable of all these Motions in Animals, which have the first Coats of the Eye absolutely solid and inflexible. Such are, for Instance, the Eyes of the Whale, which some anatomical Travellers, that have dissected them, have assured me are as hard, externally, as so many Balls of Ivory. They affirm likewise, that Whales see very well at all Distances; that without such good Eyes, they could not either give Chace to other Fish, or avoid those that are on the watch

to

to catch them, with ſo great a Sagacity as they do; and that the Opinions of ſome Authors, of their having a Fiſh to conduct and guide them, are merely fabulous. However, were Whales actually ſhort-ſighted, the Reaſon of it would be intirely diſcovered, and would be a further Proof of the Neceſſity of the Motions juſt attributed to the Eyes. But in caſe a Whale ſees at different Diſtances, its ſolid Eyes being incapable either of dilating or contracting themſelves, it is very neceſſary that the Cryſtalline Humour ſupply that Defect, by projecting, or ſubſiding, and ſo becoming more or leſs convex, thro' the Action of the Ciliary Fibres.

The Sight.

The interior Violence accompanying the Action of theſe Fibres, is what moſt ſtrains an Eye obliged to look at a near Object; and is generally that which ſo much fatigues the Eyes of thoſe that look with Application, and for a great while together, as they do who read a good deal: becauſe this Application ſuppoſes a continued Tenſion of the Ciliary Fibres in order to put and retain the Eye and the Cryſtalline Humour, in Situations proper for diſtinct Viſion.

The Pupil, when it is a perfect one, gives us a Specimen of this Contraction of the Corona Ciliaris, by a ſmall ſympathetical Contraction, which it owes to their common Origin.

Effect of the clinging of the Eye-lids.

I ſaid that one twinkles the Eye to look at a remote Object, by compreſſing the anterior Hemiſphere of the Globe, and that one dilates the

The Sight.

the Eye-lids to ſee an Object near, not inaſmuch as theſe two States of the Eye-lids are abſolutely neceſſary to give to the Globe the Figures it ought to take in the Caſes propoſed. Theſe Figures of the Globe have other Cauſes of greater Power and Force, and one may, without diſconcerting their Effects, twinkle the Eye-lids both in one and the other Caſe. We actually do ſo every time we make Efforts to ſee better, either in regard of diſtant or near Objects. But this kind of twinkling bears no Analogy with the Figure of the Globe. All its Mechaniſm terminates in ſtraitening the Eye-lids, in order to hinder the Rays from falling in too great a Quantity on the ſmooth Surface of the Cornea; from whence they are reflected and ſcattered around to the Prejudice of the Clearneſs of the Rays which enter the Eye. It is the Reaſon, why we mechanically twinkle our Eyes, to permit a Paſſage to almoſt nothing but the Cone of Light that conveys the Image, and to prevent this Image from being diſturbed, and ſoiled, if one may be allowed the Expreſſion, by foreign Rays. Hence likewiſe we ſee an Object better thro' a Tube, than in open Air.

Effect of the Contraction and Dilatation of the Iris.

It is by a like Artifice, that the Iris, which is a Part derived from the Choroides, contracts itſelf on being ſtruck by a very ſtrong Light. On which Account, it lets paſs a leſs Quantity of Rays, which affecting this Organ more moderately produce in it a diſtincter Impreſſion.

On

The SIGHT.

On the contrary, the Iris is dilated, when the Light is feeble; becaufe the Choroides, not being fufficiently ftimulated by this feeble Light, leaves the Iris in a State of Relaxation: and this very Relaxation makes the Iris, thus enlarged, receive a greater Supply of Rays. So that the Quantity of thefe Rays repairs in fome meafure their Feeblenefs, and produces an Image as diftinct as poffible.

Altho' the Eye-lids, like the Iris, concur to preferve the luminous Cone, that enters the Eye, more pure, and to render the Images more perfect; if, notwithftanding, we look at a Candle with our Eye-lids drawn fo near together, that they partly clofe the Pupil, and intercept a Portion of the luminous Cone that ought to enter it, we no longer in that Cafe fee the Candle clearly, but with great luminous Traces directed towards the upper and lower Part of this Light; which large Traces are the Portions of the Cone reflected by each Eye-lid. But the Eye-lids do not thus difturb the Sight, but when they are clofed in the manner I have been hinting; nor has the Object thefe large Traces of Light, but above and below. Thefe are Circumftances, that never entered into the Thoughts of a Naturalift *, worthy of all Efteem for his Piety, when he afcribed the Rays of the Stars to this Reflection, produced by the Eye-lids being fond of erecting this Defect to a Per-

* The Author of the Spectacle of Nature.

The Sight. Perfection destined by the supreme Being to embellish the Spectacle of the Universe.

Why the Planets are encircled with Rays. We must therefore seek elsewhere the Cause of the Rays that surround the Planets.

These Rays are of several Sorts. First, we find around the Sun, a kind of luminous Atmosphere, which almost to the Life resembles that easily observable round this Planet, and about the Moon herself, in some particular Fogs.

Secondly, we observe likewise in the Planets, and principally in the Stars, a certain trembling Motion, that subjects their Image to a perpetual Alteration of Figure; and luminous Traces and Angles seem at the same time to dart from their Circumference.

Thirdly, in short, the Sun in particular, when seen in a very clear Sky, appears surrounded with a sparkling Atmosphere, insupportable to the Eyes.

The luminous Atmosphere that encircles the Sun, is not altogether an Illusion of the Sight. It is natural enough for this intirely fiery Planet, to have at least an Atmosphere of very clear and very lively Light, and it is this Atmosphere, that is so intolerable to our Eyes *. The Mediums, the Image of the Sun passes thro' to come to us, are, perhaps, a farther Augmentation of the Appearance of this Atmosphere; because

* The celebrated Monf. *de Mairan* established this Atmosphere in his Treatise on the Light of the Zodiac.

because when these Mediums become grosser, they make the Images of all the Planets appear surrounded with a Crown of Light. If we put a fine Linen-Cloth between our Eye, and the Light of a Wax-Candle, we shall see this Candle surrounded likewise with a Circle of Light; by reason the Threads of the Cloth, which the Light of the Candle passes thro', disperse and scatter a Part of them out of the regular Cone naturally formed by this Light; and from the Portion of Light thus turned, and scattered round this regular Cone, results that remarkable Circle. Ethereal Matter, and the Earth's Atmosphere act, in regard of the Images of the Planets, what the fine Cloth does in respect of this Light.

The SIGHT.

Without putting the Cloth before a Candle, if one looks at it from the Distance of a hundred Yards, we shall see it surrounded with Rays, and Traces of Light; because the luminous Filament, which conveys this small Image, is not able to preserve its regular Figure, thro' so long a Space of Air. Hence several Pencils in the Circumference of this small Cone are turned, and rendered more divergent than the rest; and so by these small Scatterings form those Traces and Rays, that surround the Body of this Light, or principal Cone. Now, tho' the Distance of a hundred Yards be necessary for seeing a Candle encircled with Rays, that of two Feet is sufficient for seeing a Spark of Fire in the same

The Sight. ſame State; becauſe the luminous Filament of this Spark is extremely fine and feeble. The Stars, by reaſon of their Diſtance, are feeble Lights ſeen from a-far, mere Sparks, as it were, whoſe luminous Filaments are not able to preſerve their Regularity as far as us. The Moon is not encompaſſed with Rays like the leſſer Planets, becauſe her luminous Cone, being of vaſter Extenſion, makes the better Reſiſtance, in regard of the Mediums it paſſes thro', ſo that her Image arrives in a regular manner at the Bottom of the Eye. The ſmall Planets, ſeen thro' large Teleſcopes, are equally without Rays, becauſe the Glaſſes of theſe Teleſcopes collect the Rays ſcattered in the Circumference of the Image, re-eſtabliſh it, and render it regular.

As to the trembling Motion of the Planets, that proceeds likewiſe from the Mediums their Images paſs thro'; not from thoſe groſſer Mediums like the Atmoſphere, but from the ſubtile ones, ſuch as ethereal Matter, and the Matter of Light. Theſe Mediums which fill and compoſe the celeſtial Spheres, are inceſſantly in Motion, and the Motion peculiar to Light, or to its Action and Function, as Light is the Motion of Vibration. The Images of the Sun and Stars, that come to us thro' all the Spheres, muſt partake of all theſe Motions, and conſequently undergo a proportional Alteration, in regard of their Regularity. Now this Alteration is preciſely the trembling Motion that affects the

the Brilliancy of the Planets, of the Stars particularly, whoſe Image have ſeveral Spheres to paſs thro'. One has a groſs kind of Reſemblance, tho' conſtant enough, of this trembling Motion, when we look at a Star, or the Sun, reflected from the Surface of Water a little agitated.

When the Choroides is affected by too lively an Impreſſion, one ſees Sparks with it: and even a Stroke received on the Eye makes one ſee Sparks, becauſe theſe nervous Parts are very ſtrongly affected. The direct Impreſſion of the Sun on our Eyes, is certainly one of thoſe that affect this Organ too violently. Its Image of courſe muſt be accompanied and ſurrounded by Sparks. And this, in reſpect of the luminous Atmoſphere, is all that is therein remarkable. For I cannot tell from whence the regular Traces could have been taken, with which it has been encircled with Rays, unleſs from the Imagination of Painters.

To deprive the Sun of all his Rays, we have nothing more to do, than to look at this Planet thro' a Pin-hole, either on his ſetting, or in a Pail of Water. Becauſe the Impreſſion made on the Choroides in all theſe Caſes is very feeble, and conſequently void of Sparks. He is then reduced almoſt to the Condition of the Moon, whoſe ſoft Light is imprinted clearly, and without the leaſt Embaraſſment on the Choroides.

Let

The Sight.

Let us end this Essay on Vision with the Explication of some optical Phœnomena, Part of which are omitted in the Articles where they should have been ranged, and the rest having a Connexion with several Articles occur here in their natural Place.

Sequel of the Phœnomena *of* Vision.

I.

How the Images of Objects are seen reversed, which enter in the dark Chamber, and why these same exterior Objects are seen in a right Situation, when surveyed thro' the Hole of this Chamber.

WE have seen thro' all the preceding Discourse, that Images cross one another, and are reversed in the Eye, as they are in the dark Chamber. If, notwithstanding, we are in a dark Chamber, and look thro' the Hole at exterior Objects, we shall see them strait. These Objects, nevertheless, fall reversed on the transparent Cornea, as they do on the Pasteboard, subservient to the Experiment of this Chamber. In case the Eye makes them cross again, they are of course in a right Position. Now Objects painted right in the Eye must be seen reversed. So that those exterior Objects must consequently be seen reversed, which one looks at thro' the Hole of the dark Chamber.

We see the Images reversed, painted on the Pasteboard, d, d, of the dark Chamber, Fig. 2. Pl. XIII. because these Images reversed and reflected by the Pasteboard towards our Eyes, e, cross once more in these Organs; and go to be painted in a right Situation on the Choroides: and

The SIGHT.

and theſe reflected Images croſs again in the Eye, by reaſon their Rays are parallel, or convergent. Exterior Objects, ſeen immediately thro' the Hole of the dark Chamber, would equally be ſeen reverſed, did their Images likewiſe croſs in the Eye. But this is not the Caſe. They fall in the Bottom of the Eye reverſed, Fig. 3. as they are on the Cornea, and on the Paſteboard; becauſe theſe immediate Rays, far from being parallel, or convergent, like the Rays reflected by the Paſteboard, d, d, are extremely divergent: inſomuch, that it is impoſſible for the Humours of the Eye to make them croſs again. Theſe Humours only collect them, as the convex Glaſs does, placed at the Hole of the dark Chamber, and nothing more. See Fig. 2, 3, Pl. XIII; where theſe Truths are expreſſed. A, Fig. 2, is a Steeple ſeen thro' the Hole c, of a dark Chamber; d, d is its Image painted reverſed on the Paſteboard. The Reaſon why it is ſeen reverſed, is becauſe the Rays reflected towards one's Eye, e, croſs afreſh, and thereby rectify the Steeple. In Fig. 3, the Eye D looks at the Steeple A immediately thro' the Hole C of this Chamber. The Rays C D being too divergent, cannot croſs in the Eye D. Hence they paint the Steeple reverſed, as if one looked at it out of the dark Chamber, and on that account, we ſee it in a right Situation.

All

The Sight.

All the World knows, that, in order to rectify Objects in the dark Chamber, we must place at the Hole of this Chamber two lenticular Glasses; to wit, the first at the Hole itself, C, Fig. 5. the second E separated from the former a little more than two Foci of these Glasses. The first Glass C brings back the divergent Rays, C, towards the Parallel. The second Glass E recovers these parallel, or almost parallel, Rays, makes them cross afresh, and thus rectifies the Image in F. This Image appears right to the Eye D, because being reflected by this Eye, it there crosses and is reversed, as if the Image came directly from the Object A. Consequently, neither the first Glass, nor the Eye, is capable of making the Rays cross, and so rectify the Images at the Bottom of the Eye, as we see it does, Fig. 3. These Images then will be there reversed, and the Object seen thro' the Hole of the dark Chamber would appear right.

II.

How a Pin in a right Situation may appear reversed.

The Hole of the dark Chamber, that exhibits Objects reversed on the Pasteboard, d, d, lets them notwithstanding be seen witho ut in a right Situation. But here follows another Experiment, where, on the contrary, a right Object disposed before, and within this Hole, appears reversed and placed on the Outside of this Chamber.

With-

Without recurring to a dark Chamber, put before your Eye D, (Fig. 4, Pl. XIII.) a black Paſteboard, B, pierced with a Pin-hole, C. Place over againſt and beyond this Hole, a very illumined Body, ſuch as a Sheet of white Paper, E, enlightened by a Flambeau, G. Hold afterwards a Pin, d, before your Eye, D, and you will ſee with Surprize the Pin reverſed, and on the other Side of the Hole in F. Which Phœnomenon is thus accounted for. The SIGHT.

The Images of exterior Objects, it is well known, in paſſing thro' the Hole, C, Fig. 2, 3, are reverſed, and painted thus reverſed, either on the Paſteboard, d, d, or in the Eye, D. The ſame Thing happens in regard of the Images which paſs thro' the ſimple Pin-hole, c, Fig. 4. and goes to be painted in the Eye, D. At the Place where the Pin in a right Situation, d, is put, the Images are already reverſed. Now this Pin occurring with theſe reverſed Images, ſtops the Rays that correſpond with it, and, conſequently produces in theſe Images a Deficiency of Rays, or the Shadow of the Figure of a Pin. This Pin in the midſt of this reverſed Image is right. The Image of the Paper, E, will therefore go to be painted at the Bottom of the Eye in a reverſed manner, having in the middle of it a Shadow of a Pin in a right Situation. Now the Soul judges Objects right, that are reverſed in the Eye, and reverſes thoſe that are there right. Whence ſhe will ſee

The SIGHT.

the exterior Objects, E, in a right Situation, and the Shadow of the Pin reverſed. She will moreover ſee this Pin, or rather its Shadow, beyond the Hole in F; becauſe the Pin ſhe ſees is only in Effect a Shadow produced in the Image of the exterior Objects, E. This imaginary Pin ought therefore to be the exterior Objects, E, and ſeen beyond the Hole.

III.

Why the quick twirling about of a burning Coal ſeems a Circle of Fire.

The Eye is not only deceived in regard of the Situation of Objects, by ſeeing thoſe reverſed that are right, and thoſe right that are reverſed; but is ſtill more frequently deluded, and with leſs Art, as well in reſpect of the Situation, as of the Figure of Objects, when a lighted Charcoal whirled around ſhall ſeem a Circle of Fire; or when a very ſmall Fiddle-ſtring ſhall be made to appear large, or ſeem to be ſeveral on the Side of one another, by ſolely exciting Vibrations in this fine and ſingle String.

Theſe Phœnomena depend on the Duration of the Senſations, which an Object excites in the Nerves, and on the Quickneſs with which the Action of it is repeated. When a Spark of Fire burns us, the Smart continues for a while, after the Spark is extinguiſhed; and the Impreſſion of Savours and Odours remains likewiſe a certain Time, after the Objects have ceaſed to affect the reſpective Organs. In like manner,

altho'

The SIGHT.

altho' Light be of a much more ſubtile Nature, its Impreſſion nevertheleſs ſubſiſts a limited while after its Action. Now if the Action of an Object is renewed on a nervous Papilla, before its former Impreſſion is extinguiſhed, the Impreſſions will be continued, as if the Object had not ceaſed to act. This is the Caſe in regard of the fiery Circles produced by the frequent and rapid Whirling of a burning Coal thro' the ſame Track. Its Actions on the ſame nervous Papillæ of the Choroides ſucceed one another, with ſuch Rapidity, that the Impreſſions they there excite are continued; ſo that having in the Eye an uninterrupted Circle of the Impreſſion of Fire, we neceſſarily ſee a fiery Circle. This is the Reaſon likewiſe, why Drumſticks by a rapid Succeſſion of one another on beating this Inſtrument, produce the continued Noiſe called the *Ruff*. The String of a Violin enlarged or multiplied by Vibrations are explained by the ſame Principle.

A Light, that rapidly traverſes a Space in the Heavens, ſeems there ſtill a continued one, Becauſe the Line of lively Impreſſion it deſcribes in the Eye, is made with that Celerity, that all the Points of this Line of Impreſſion ſubſiſt at once a certain Time. Conſequently, one has in the Eye an intire Line of luminous Impreſſion, and therefore one muſt ſee a continued Light. Such are thoſe Meteors, ſtiled by the Vulgar, *Falling Stars*.

The Sight.

Observations on the Sight of a distant Object, and that of a Wire placed very near the Eye on the same Line.

IV.

I looked at a distant Steeple with one Eye, and put before it a Wire not so thick as my Pupil is large. I saw the Steeple notwithstanding the Wire, and as it were thro' the Wire, which appeared to me like a thick Shade corresponding with the Steeple. I saw nevertheless this Steeple intirely. I afterwards looked at the Wire itself, and saw it distinctly without Shade, and smaller than the Shadow I saw of it on looking at the Steeple. But it was not all transparent, and, tho' absolutely very small, hid from me a Part of the Steeple. This Steeple in its turn, which I saw without looking at it on the Side of the Wire, appeared to me a great deal smaller than when I looked at it directly.

When I looked at the Steeple directly, I had my Eye contracted, and flatted by the Poles, in order to receive the luminous Cone, at the optic Point, and I saw it distinctly, and in its natural Magnitude. In this State, the Choroides too much projected for the luminous Cone of the Wire, and the Pencils of the same luminous Points reached this Choroides befor their Re-union, and reached it besides separated from one another, and leaving void Spaces between them. Hence, when I passed the Wire before my Eye, it seemed to me like an enlarged and transparent Shadow.

I

I ſaw the Steeple thro' this Shadow, becauſe the Separation of the luminous Pencils of the Wire, left Spaces large enough for the diſtinct Reunion of the optic Pencils of the Steeple. The SIGHT.

When I looked at the Wire itſelf, I ſaw it diſtinctly and ſmaller, becauſe I then dilated my Eye, and determined my Choroides to the Point, where the luminous Pencils of this near Object went to reunite themſelves diſtinctly, and by reaſon in this Point the Pencils are reduced to a ſmaller Space. The Wire at that Time, tho' not ſo large, hid from me Part of the Steeple, becauſe the luminous Pencils of the Wire, being very compact, left no more Space for thoſe of the Steeple correſponding with them, and thus totally effaced them. This Steeple, ſeen on the Side of the Wire, and without looking at it directly, ſeemed ſmaller than when I did look at it, becauſe when its Image fell on my Eye, it became more convex, in order to ſee the Wire; and this Figure of my Eye produced a large Refraction in the Image, which was rendered ſo much the ſmaller in it.

V.

To theſe Obſervations, that regard the Diſtinction and Magnitude of Images, I will add ſome others of a very ſingular Nature, occaſioned by the former. New Optical Phœnomena.

The SIGHT.

Objects magnified by the Interposition of a Wire, or a Pinhole.

As I was looking at the same Steeple, and frequently passing a Wire backwards and forwards, before my Eye, I casually perceived with Surprize, that every time the Wire passed before my Pupil, the Steeple seemed to move and leap, as if I had passed before my Eye the Glass of a Telescope. The Mountains that were behind the Steeple had intirely the same Motion.

On a closer Examination of the Matter, I observed that the only Case, where the Steeple did not leap, was when I made use of a certain very narrow Medium, and a very difficult one to keep. There the Image of the Steeple was not so distinct, and seemed to me enlarged.

I was struck with these Circumstances, that obliged me to observe in the Wire a kind of Lenticular Glass. For I surmised even at first, that the Steeple seemed to move, inasmuch as the Wire, being placed in the middle of its Ray, enlarged the Image of this Steeple, and because, on the Wire's being past that middle, and the enlarged Image's suddenly resuming its ordinary narrow Bounds, the Steeple looks as if it were in real Motion; as an Object, before which one passes a Lenticular Glass, appears refracted and moved.

In order to be assured of the Reality of this Conjecture, I accommodated my Eye to the Steeple in such a Manner, that its Image came to my Eye glancing very near the Side of the Window,

Window, where I obſerved it. I again paſſed my Wire, and ſaw that, when it was in the viſual Axis of the Steeple, the latter ſeemed nearer the Window, on whatever Side the Wire came; becauſe the Image of the Steeple enlarged by the Wire diminiſhed in that Proportion the Space I had made between theſe two very near Objects. I obſerved likewiſe, that when this Image was contracted, by withdrawing the Wire, it was ſo much the more remote from the Window. Hence, on executing with Celerity what I had been doing deliberately, the Steeple ſeemed to leap on its approaching to, and retiring from the Window.

The SIGHT.

After this Confirmation of my former Conjecture, I repeated the Experiment in a very clear Seaſon, which ſtill equally ſucceeded. And the Wire, being held fixed and exactly in the middle of the Steeple, never fails to make it appear a great deal larger, and as it were double. The phyſical Cauſe of this ſingular Phœnomenon is as follows.

This Medium, where the Image of the Steeple is confuſed, larger, and as it were double, is when the Wire is exactly in the Axis of the Image of the Steeple. In this Situation, the Wire divides the luminous Cone, that conveys this Image into two equal Parts, and intercepts the perpendicular Filament of it, which is what contributes to render the Image incompleat and confuſed.

The Sight.

The Confusion of the Image of the Steeple is all one can attend to, from the Interposition of such a Body as a Wire: it is notwithstanding much less perceptible than its Enlargement.

The Confusion is slight: Therefore the Wire intercepts but few Rays. It is nevertheless of such a Thickness, that it ought to hide from me at least the whole Steeple; for I see an intire Plain, of which the Steeple does not make a hundred thousandth Part. The Wire is almost a Line thick, my Pupil thro' which the Image of all this Plain passes, contains but a Line and a half, or two Lines at most, and the Wire is only the Length of an Inch of it. Conceive then a Cone of Light, with a Base more than a hundred thousand Times as large as the Steeple, and place within an Inch of its Top an opaque Line, and you will see what an Angle this Line will describe on the Base of the Cone, and how many Steeples it will cover.

It therefore necessarily follows, that the greatest Part of the Rays, which occur to the Wire, are not stopped by it and extinguished; for a great many of them are requisite in order to one's seeing the Steeple. On the contrary, these Rays must circulate a little round the Wire, or turn from their right Line to accommodate themselves to its Circumference, somewhat like what a Filament of Water or Air would do. By means of this turning, our Eye will

have

have almoſt the whole Image of the Steeple, which of courſe will be very little confuſed. The SIGHT.

That is not all. This Image of the Steeple appears enlarged. Now an Inſtrument that enlarges an Image, only does ſo by rendering its Rays convergent, or at leaſt by making them croſs in a wider Angle. Thus, as the Wire enlarges the Image of the Steeple, it neceſſarily follows, that as one half of its Circumference which fronts the Object, turns and renders the Rays of the Steeple divergent, ſo the other that fronts the Eye, turns theſe ſame Rays convergently towards this Organ. There is therefore thro' the whole Circumference of the Wire, a certain Power, that collects towards the Eye theſe ſame Rays which it had at firſt ſcattered. To that End this Power muſt of courſe apply theſe Rays to the Circumference of the Wire, and oblige them to follow this Circumference even to a particular Point. In a Word, the Circumference of the Wire muſt in regard of theſe Rays be endued with an Attraction intirely like that obſervable in Glaſs. Now we have ſeen that this Attraction is nothing elſe than an Impulſe of the Fluid which ſurrounds the Wire; and that theſe Rays are thus applied to the Wire, as a Filament of Water is to a Stick, or a Piece of Liſt preſented to it.

This ſurrounding Impulſe therefore determines theſe Moieties of the Image to turn round the Wire, and by that means makes the whole

The Sight. whole Image appear double. This Impulſe likewiſe retains theſe ſame Moieties, as much as poſſibly it can, againſt the Circumference of the Wire, which Effort produces a Turning of theſe Rays towards the viſual Axis. Conſequently they croſs with greater Celerity, and in a larger Angle, and of courſe form a larger Image.

Thus then are Rays refracted in Convergence, and an Object enlarged by a Wire, in the ſame manner as it is by a Lenticular Glaſs; what has never, I imagine, been before ſurmiſed.

Not only the narrower luminous Cone, paſſing in the Eye, without the Wire, occurs thus collected in Convergence; but the Wire likewiſe becoming thicker than this firſt Cone, its Surface muſt neceſſarily attract the collateral Rays, or Portions of a larger Cone, and collect this larger Cone in Convergence in the Bottom of the Eye, which of courſe muſt produce a larger Image.

In order to convey a clearer Idea of this Phœnomenon, and its Explication, I muſt deſire the Reader to conſult Fig. 2, Pl. XIV. The black Lines deſcribe the narrow luminous Cone that conveys the natural Image of the Steeple A, to the Eye B, when the Wire is not before the Pupil, where it is evident, the natural Cone is much narrower than the Wire C. The pointed Lines not only mark the firſt luminous Cone ſtopped

stopped and turned by the Wire C; but they describe likewise the collateral Rays more scattered, which are attracted by the Wire, and collected in Convergence in the Pupil, in the same manner as we have seen in the Plate of Pl. XII. Fig. 2, the Lenticular Glass assembles in the Pupil the collateral Rays g, h, which would not have been entred there without this Refraction; and by that means the pointed Cone, thus collected in the Bottom of the Eye B, makes there a larger Angle, and a larger Image, than the Cone marked by the black Lines, which is the natural one. As to what remains, the Experiment equally succeeds with every other Body as with the Wire, provided it be as narrow.

The Sight.

This Discovery, which depends on the Inflexion of Rays, towards the Surface of Bodies, has conducted me to several others depending on the same Principle. For Instance, I have also enlarged small Objects, such as a Pin's Head, by looking at them thro' a very little Hole, made in a Pasteboard, in such a manner, that the Image might sufficiently approach to the Circumference of the Hole to be stopped by it and enlarged. I have moreover remarked, on looking at some singular Objects, such as a live Coal amidst Cinders, or a Piece of fresh Charcoal, just thrown into the Fire, *&c.* that if one draws one's Finger, very near the optic

Objects enlarged and attracted by the Proximity of the Surface of Bodies.

Cone

The SIGHT.

Cone that conveys its Image to the Eye, this Object appears to dilate itself towards the Finger, and, as it were, to precede it; and that when the Finger withdraws from it, it seems still to lengthen itself, in order to follow it to a certain Point. It is for the same Reason, that the Clouds which pass before the Sun, impart different Motions to the Shadows of Bodies, and that when these Clouds are interrupted here and there, those Shadows seem as it were to dance. This Effect is principally perceptible in the Shadows formed by the Lead of Glass-windows. It is also to this kind of Refraction of Rays, by the Fluid which surrounds Bodies, that I partly ascribe the Colours of a Rainbow, produced by a very thin Pin placed near my Eye, and on which I have caused to fall obliquely the Light of a Wax-Candle.

Colours of the Rainbow produced by a Pin.

It is now Time to conclude this Essay on the Senses; and, perhaps it may be objected I ought to have done so sooner, having by a great deal surpassed the Bounds I prescribed to myself. But how can one resist the Torrent of curious Matters, that present themselves under these Articles! And yet how many have I let pass with Regret, circumscribed by these same too narrow Limits? The Nature and Mechanism of the Senses constitute a Matter the most interesting of all Physics. These are our means of Correspondence with the rest of the Universe.

It

It is the Reafon, why this Part of Phyfiology is fo linked with all the Parts of natural Philofophy, that it is almoft impoffible to treat of the Senfes, without touching at the fame Time, flightly at leaft, on the other Branches of Phyfics.

The SIGHT.

I have above remarked, that this Commerce between the Univerfe and us, is ever carried on by a Matter which affects fome Organ; and that from the Touch to the Sight this Matter is more fubtile, more and more diffufed at a Diftance from us, and on that account more and more capable of extending the Bounds of our Commerce. Bodies, Liquids, Vapours, Air, Light. This is the Gradation of thefe Correfpondences, and the Senfes by which they are carried on are our Interpreters, and our Intelligencers. It is obfervable, that the greater the Diftance is from whence our News arrives, the more fubject it is to Uncertainty; which is verified in moft of our Relations of long Voyages. The Touch, the moft limited of the Senfes, is at the fame time the fureft of them all. The Tafte and the Smell have likewife a fufficient Certainty: but the Hearing is in many Inftances too apt to deceive us. As to the Sight, Vifion is fubjected to fuch a Number of Errors, that the Induftry of fome particular Perfons, fkilled in drawing Advantages from every Circumftance, have invented Projects and formed them into an Art, on purpofe to impofe on the Eyes: an Art

The Senfes are the Means of our correfponding with the Univerfe.

The SIGHT.

Art so admirable, and carried so far by Painters, and even by those of the most remote Antiquity, that we are thereby deprived of a Possibility of having Senses that could less deceive us.

Every Thing is conjectural, unless we take the Senses for our Guides.

Our Senses are subjected to a thousand Mistakes; and yet we know nothing, but what they apprize us of, or what they give us Grounds to conjecture, by comparing those Hints with what they demonstrate to us. For Instance, Light, the particular Fluid that renders Bodies visible, puts us on imagining there is another Fluid that gives them Gravity, another that makes them electrical, or determines the Needle to turn to the North, *&c.* And we endeavour to guess at the Figure and Motion of these imaginary Matters. Let us attend to the Train of Conjectures, and we can be under no manner of Doubt, but that all our Knowledge is at best derived from what the Senses point out to us.

Our Ignorance proceeds from the small Number and Uncertainty of the Senses.

Judge from hence of the strait Bounds, and of the little Certainty there is in our Acquaintance with Things, which consists in seeing a Part of them, by the Help of deceitful Organs, and in divining the rest. How comes Nature, you will say, to be so good and so liberal? Has she not furnished us with Senses for all these Phœnomena, which we are constrained to guess at; for

for Inſtance, for this Fluid of Gravity; for that which moves the Needle; for what gives Life to Plants, to Animals, *&c?* A Method more conciſe of rendering us intelligent, in reſpect of theſe natural Effects, which otherwiſe become Myſteries. For, in ſhort, the five Species of Senſation, which are Embaſſadors, as it were in our Regard, from the States of the material World, can only ſupply us with a ſlight Idea of them. Let us imagine to ourſelves a Sovereign of the Univerſe, who had no other Notion of all the People ſpread over the Face of the Earth, than what he had received from a *Frenchman*, a *Perſian*, an *Egyptian*, and a *Creolian*, and all four deaf and dumb. For of this Kind are more or leſs all the Species of Matter. It is true, modern Philoſophy has diſcovered Prodigies of Invention to interrogate theſe Embaſſadors. But ſuppoſe they will one Day reveal themſelves to us, there is ſtill no Appearance that they will ever unfold what all the other Nations of Matter are, that are foreign to them.

The SIGHT.

It is a Point worthy our Conſideration, that Senſes more multiplied than ours, might poſſibly have embarraſſed us, or that the greedy Curioſity they had inſpired us with, might have been the Source of more Inquietude than Pleaſure. Is not the good Uſe of thoſe we have, ſufficient

to

The SIGHT.

to our Happiness? Let us then congratulate ourselves, as Philosophers, in the Privation of these imaginary Riches, by employing those well which we are blessed with the Enjoyment of. This is our Destination, the Will of the supreme Being, and the End of all sound Philosophy.

FINIS.

[illegible]